Lunar Landing Research Vehicle

WEIGHT and BALANCE HANDBOOK

REPORT NO. 7161-954002

1 APRIL 1964

MANUFACTURED

BY

BELL AEROSYSTEMS COMPANY
DIVISION OF BELL AEROSPACE CORPORATION-A textron COMPANY

FOR NATIONAL AERONAUTIC AND SPACE ADMINISTRATION
CONTRACT NAS 4-234

FOREWORD

The majority of the weights, arms, and moments in this Handbook are based on calculations. Actual weighed and measured values should be substituted when they become available.

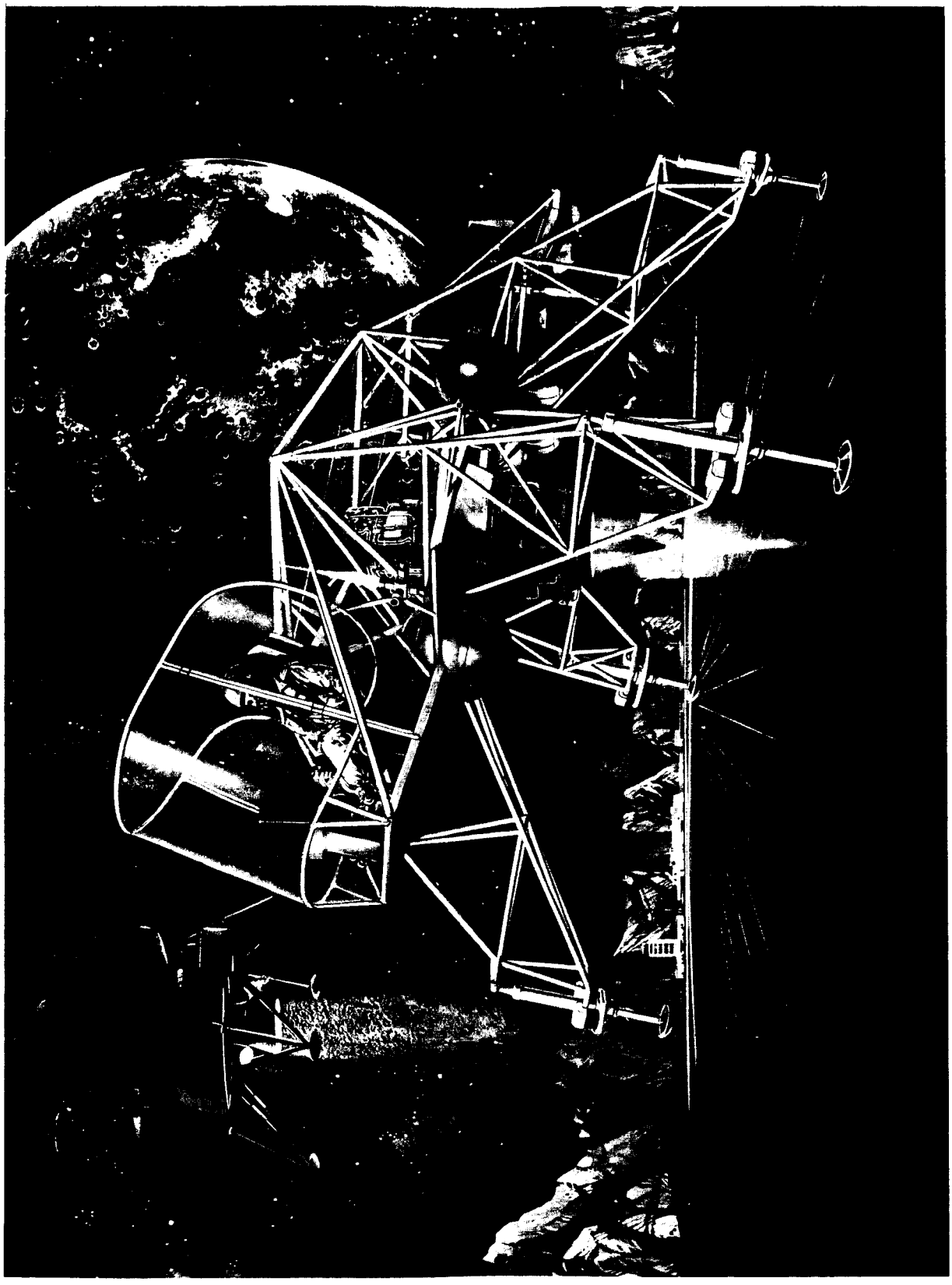
All weights and arms are taken from detail weight records but are all rounded off to the nearest tenth of a unit. Therefore, the product of weight and arm may deviate slightly from the moment value shown.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

INDEX TO FORMS



Lunar Landing Research Vehicle

SECTION I

TECHNICAL DATA

1.1. DEFINITIONS.

1.1.1. Basic Weight. - Basic weight is defined as the weight of the Lunar Landing Research Vehicle (LLRV) and its normal operational equipment. (See Figure 1-1.) It includes the weight of the hydraulic and engine oil systems filled to capacity, and the helium pressurization gas under normal operating pressure. It also includes the weights of JP4 fuel and hydrogen peroxide contained in the distribution and supply lines from the tank outlets to the engine fuel pump and solenoid valves respectively.

1.1.2. Operating Weight Empty. - Operating weight empty is defined as the basic weight plus the weight of the fully equipped pilot.

1.1.3. Gross Takeoff Weight. - Gross takeoff weight is defined as the weight at the moment of lift-off. It is obtained by adding the weights of JP4 and hydrogen peroxide fuels contained within the fuel tanks to the operating weight empty. It does not include the weight of fuels used in runup and checkout and is subject to limitations governed by takeoff altitude and ambient temperature.

1.2. GROSS TAKEOFF WEIGHT LIMITATIONS.

The allowable gross takeoff weight is contractually limited to 95.5 percent of the installed jet engine thrust at takeoff rating. (Refer to the LLRV Flight Manual, Bell Aerosystems Company Report 7161-954005, for information regarding determination of the maximum allowable gross takeoff weight.) The maximum allowable gross takeoff weight is not limited by structural considerations.

1.3. CENTER OF GRAVITY LIMITS.

1.3.1. Vertical Center of Gravity Limits. -

1.3.1.1. Vehicle Without Gimballed Items. -

0.0 to 0.5 inch below WL 200 (gimbal ℄) at gross takeoff weight.

0.0 to 0.5 inch below WL 200 (gimbal ℄) at operating weight empty.

1.3.1.2. Gimballed Items (Gimbal Ring and All Items Supported Thereby). -

0.0 to 1.5 inches below WL 200 (gimbal ℄).

1.3.2. Lateral and Horizontal Center of Gravity Limits. -

±0.25 inch from intersection of pitch and roll reference axes (center of gimbals) for all combinations of vehicle and engine at all weights.

1.4. LEVELLING PROVISIONS.

Two sets of levelling lugs are provided on the vehicle. They are located on the main structural ring and provide means for determining pitch and roll angles. The locations of the levelling lugs are identified in Figure 1-2.

1.5. WEIGHING DATUMS.

No jig points are provided on the vehicle. The datum for all measurements of lateral and horizontal centers of gravity is the engine centerline. The datum for measurement of the vertical center of gravity is the horizontal plane through the gimbal axes.

1.6. REFERENCE AXES.

The reference axes are a standard set of orthogonal roll, pitch, and yaw axes, designated the x, y, and z axes, respectively. (See Figure 1-2.)

1.7. REFERENCE DATUMS.

Reference datums are located 200 inches from the intersection of the reference axes. (See Figure 1-2.)

1.8. HELIUM GAS DATA.

The weights and moments for helium gas are shown in Table 1-1. The values shown are calculated; actual measured values should be substituted when they become available.

1.9. ENGINE OIL DATA.

The weight and moment for engine oil is shown in Table 1-2. The values shown are calculated; actual measured values should be substituted when they become available.

1.10 CREW DATA.

Weights and moments for various weights of pilots are shown in Table 1-3. The values shown are calculated; actual measured values should be substituted when they become available.

TABLE 1-1

HELIUM GAS DATA

TANK PRESSURE PSIA	WEIGHT OF HELIUM (TWO TANKS) POUNDS W	ARM INCHES x	MOMENT POUND-INCHES Wx	ARM INCHES y	MOMENT POUND-INCHES Wy	ARM INCHES z	MOMENT POUND-INCHES Wz
3500	4.64	270.0	1253	200.0	928	191.5	888
3250	4.34	270.0	1172	200.0	868	191.5	831
3000	4.04	270.0	1091	200.0	808	191.5	774
2750	3.73	270.0	1007	200.0	746	191.5	714
2500	3.42	270.0	923	200.0	684	191.5	655

Figures based on constant gas temperature of 50 degrees F.

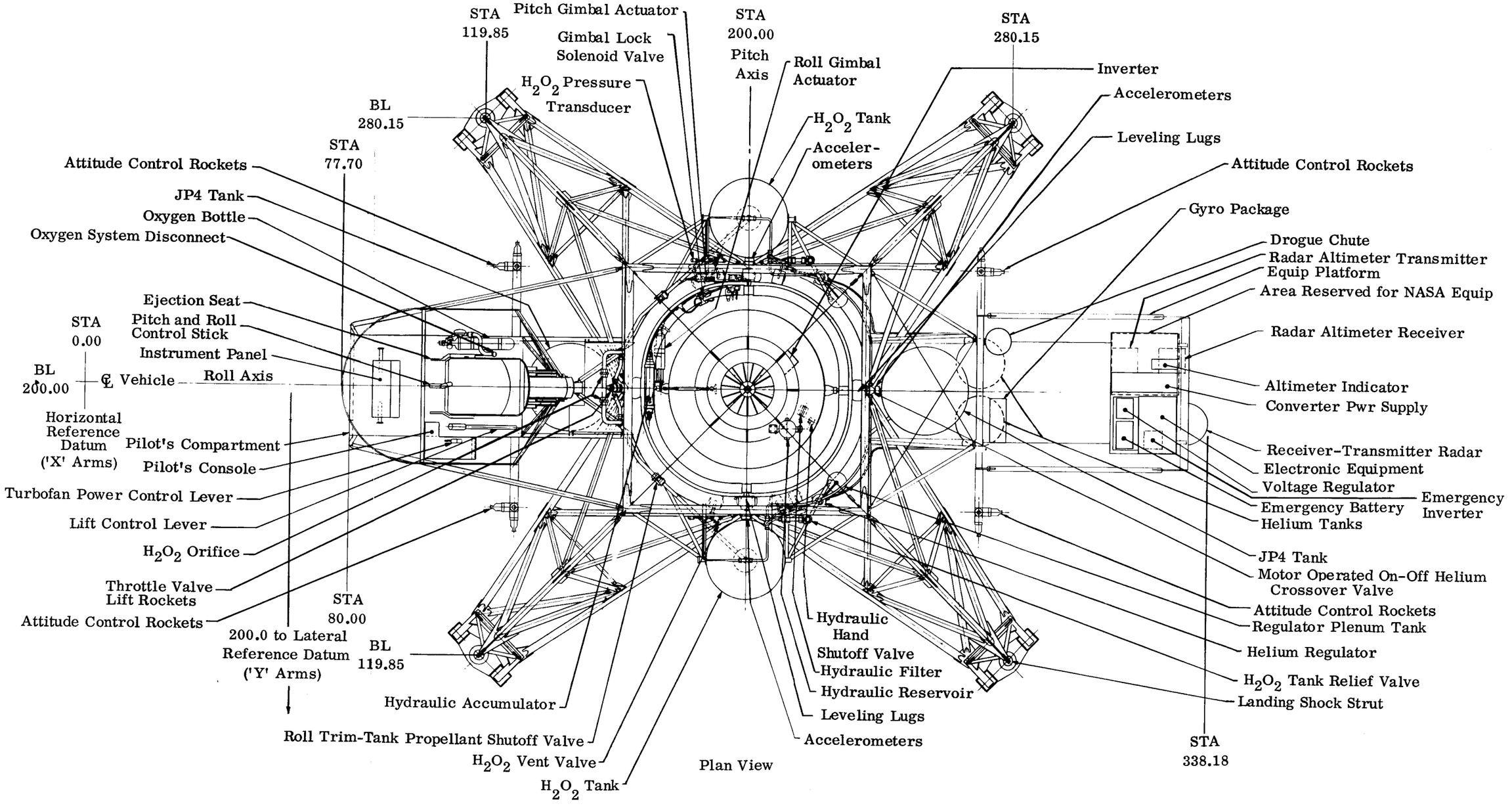
TABLE 1-2

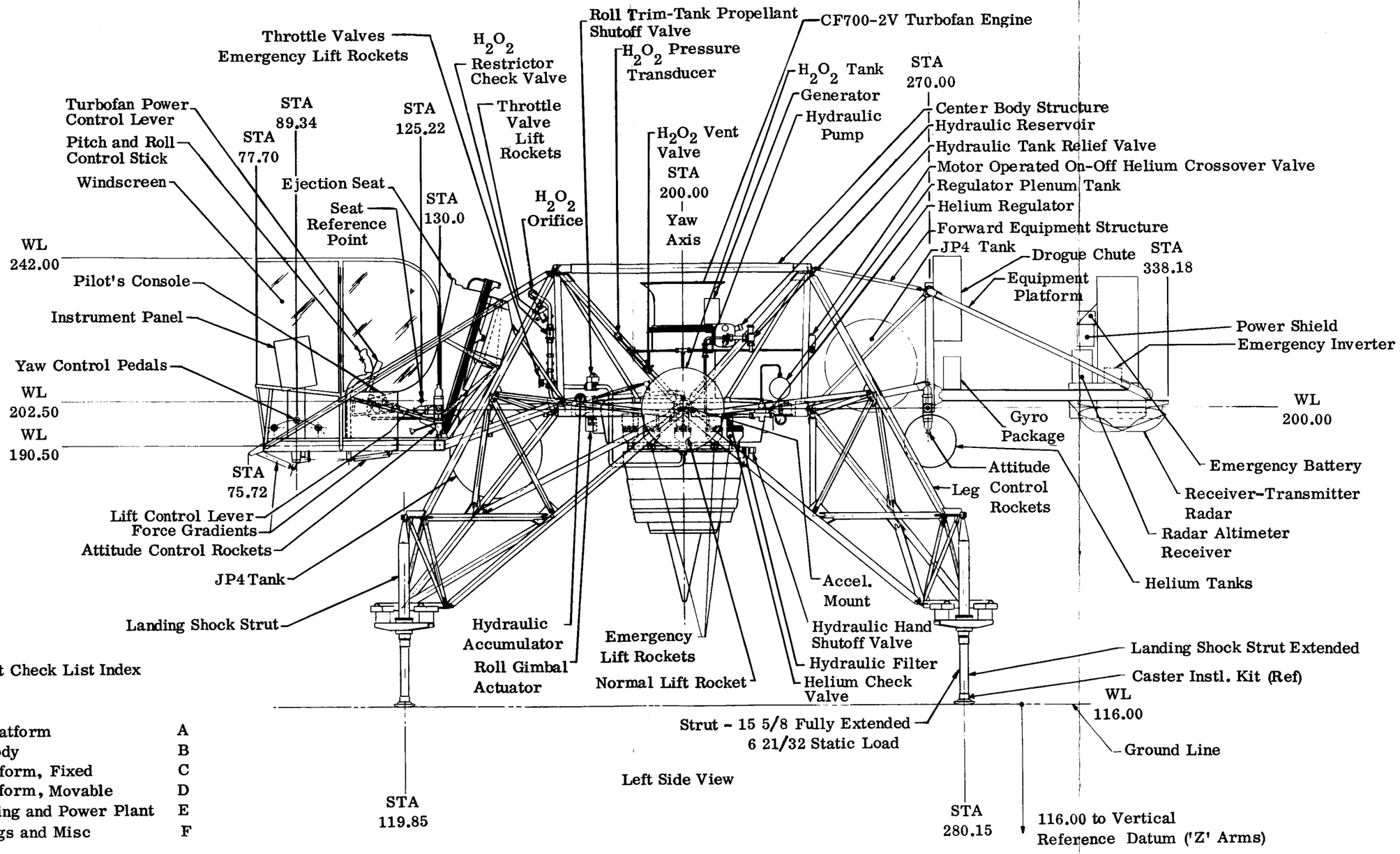
ENGINE OIL DATA

ENGINE OIL RESERVOIR 1.0 U.S. GALLON CAPACITY							
U.S. GALLONS	WEIGHT POUNDS* W	ARM** INCHES x	MOMENT POUND-INCHES Wx	ARM** INCHES y	MOMENT POUND-INCHES Wy	ARM** INCHES z	MOMENT POUND-INCHES Wz
1.0	7.50	194.0	1455	189.0	1418	188.4	1413

* Based on lubricating oil Specification MIL-L-7808E, 7.50 pounds per U.S. gallon at 60 degrees F.

** Engine vertical.


STA 119.85
Pitch Gimbal Actuator
Gimbal Lock Solenoid Valve
STA 200.00
Pitch Axis
Roll Gimbal Actuator
STA 280.15
Inverter
Accelerometers
H_2O_2 Pressure Transducer
BL 280.15
H_2O_2 Tank
Acceler-ometers
Leveling Lugs
STA 77.70
Attitude Control Rockets
JP4 Tank
Oxygen Bottle
Oxygen System Disconnect
Gyro Package
Drogue Chute
Radar Altimeter Transmitter
Equip Platform
Area Reserved for NASA Equip
Ejection Seat
Pitch and Roll Control Stick
Instrument Panel
Radar Altimeter Receiver
STA 0.00
BL 200.00
℄ Vehicle
Roll Axis
Altimeter Indicator
Converter Pwr Supply
Horizontal Reference Datum ('X' Arms)
Pilot's Compartment
Pilot's Console
Receiver-Transmitter Radar
Electronic Equipment
Voltage Regulator
Turbofan Power Control Lever
Lift Control Lever
H_2O_2 Orifice
Emergency Battery
Emergency Inverter
Helium Tanks
JP4 Tank
Motor Operated On-Off Helium Crossover Valve
Throttle Valve Lift Rockets
Attitude Control Rockets
Attitude Control Rockets
Regulator Plenum Tank
STA 80.00
200.0 to Lateral Reference Datum ('Y' Arms)
BL 119.85
Hydraulic Hand Shutoff Valve
Hydraulic Filter
Helium Regulator
Hydraulic Reservoir
H_2O_2 Tank Relief Valve
Hydraulic Accumulator
Leveling Lugs
Landing Shock Strut
Roll Trim-Tank Propellant Shutoff Valve
Accelerometers
STA 338.18
H_2O_2 Vent Valve
Plan View
H_2O_2 Tank



Left Side View

Equipment Check List Index

Pilot's Platform	A
Center Body	B
Rear Platform, Fixed	C
Rear Platform, Movable	D
Gimbal Ring and Power Plant	E
Truss Legs and Misc	F

Figure 1-2. LLRV General Arrangement

TABLE 1-3

CREW DATA

PILOT* WEIGHT POUNDS W	ARM** INCHES x	MOMENT POUND-INCHES Wx	ARM INCHES y	MOMENT POUND-INCHES Wy	ARM** INCHES z	MOMENT POUND-INCHES Wz
230	120.2	27,646	200.0	46,000	215.4	49,542
220	120.2	26,444	200.0	44,000	215.4	47,388
210	120.2	25,242	200.0	42,000	215.4	45,234
200	120.2	24,040	200.0	40,000	215.4	43,080
190	120.2	22,838	200.0	38,000	215.4	40,926
180	120.2	21.636	200.0	36,000	215.4	38,772
170	120.2	20,434	200.0	34,000	215.4	36,618
160	120.2	19,232	200.0	32,000	215.4	34,464
150	120.2	18,030	200.0	30,000	215.4	32,310

*Pilot weight includes all clothing and equipment worn or carried to the vehicle, but does not include the weight of the parachute.

**All centers of gravity are based upon the seat reference point at the centerline of the seat in the neutral position (Reference MS 33575).

1.11. JP4 FUEL DATA.

The weights and moments for varying quantities of JP4 fuel contained in the fuel tanks are shown in Table 1-4. The weight and moments for all JP4 fuel elsewhere in the fuel system (i.e., between tank outlets and engine fuel pump) are shown in Table 1-5. This fuel is part of the vehicle basic weight. (See Paragraph 1.1.1.). The maximum volume of fuel in each tank with filler cap open is calculated as 34.4 U.S. gallons. Ensure that the fuel weight difference between the two tanks does not exceed one pound at takeoff. All values shown in the fuel tables are calculated; actual measured values should be substituted when they become available.

TABLE 1-4

JP4 FUEL IN TANKS

TOTAL LOADED* WEIGHT POUNDS (TWO TANKS) W	VOLUME U.S. GAL-LONS (TWO TANKS)	ARM** INCHES x	MOMENT POUND-INCHES Wx	ARM** INCHES y	MOMENT POUND-INCHES Wy	ARM** INCHES z	MOMENT POUND-INCHES Wz
447	68.8	200.0	89,400	200.0	89,400	199.1	89,018
425	65.4	200.0	85,000	200.0	85,000	198.7	84,433
400	61.5	200.0	80,000	200.0	80,000	198.2	79,294
375	57.7	200.0	75,000	200.0	75,000	197.7	74,154
350	53.8	200.0	70,000	200.0	70,000	197.2	69,036
325	50.0	200.0	65,000	200.0	65.000	196.8	63,958
300	46.2	200.0	60,000	200.0	60,000	196.3	58,892
275	42.3	200.0	55,000	200.0	55,000	195.8	53,857
250	38.5	200.0	50,000	200.0	50,000	195.3	48,836
225	34.6	200.0	45,000	200.0	45,000	194.8	43,840
200	30.8	200.0	40,000	200.0	40,000	194.3	38,869
175	26.9	200.0	35,000	200.0	35,000	193.8	33,923
150	23.1	200.0	30,000	200.0	30,000	193.1	28,972
125	19.2	200.0	25,000	200.0	25.000	192.6	24,074
100	15.4	200.0	20,000	200.0	20,000	192.0	19.204
75	11.5	200.0	15,000	200.0	15,000	191.3	14,351
50	7.7	200.0	10,000	200.0	10,000	190.5	9,527
25	3.8	200.0	5,000	200.0	5,000	189.5	4,739

*Table based on JP4 fuel at 6.5 pounds per U.S. Gallon at 60 degrees F.
**Vehicle in level attitude.

TABLE 1-5

JP4 FUEL IN LINES

TOTAL WEIGHT W POUNDS	VOLUME U.S. GALLONS	ARM x INCHES	MOMENT Wx POUND-INCHES	ARM y INCHES	MOMENT Wy POUND-INCHES	ARM z INCHES	MOMENT Wz POUND-INCHES

Vehicle in level attitude

1.12. HYDROGEN PEROXIDE DATA.

The weights and moments for varying quantities of hydrogen peroxide contained in the tanks are shown in Table 1-6. The weight and moments for all hydrogen peroxide elsewhere in the system (i.e., between the tank outlets and thruster solenoid valves) are shown in Table 1-7. This amount of hydrogen peroxide is part of the vehicle basic weight. (See Paragraph 1.1.1.). The maximum volume of hydrogen peroxide in each tank is calculated as 28.85 U.S. gallons with no ullage space. Ensure that the hydrogen peroxide weight difference between the two tanks does not exceed one pound at takeoff. All values shown in the hydrogen peroxide tables are calculated; actual measured values should be substituted when they become available.

1.13. BALLAST.

This vehicle is not intended to carry ballast and no special means for attachment of ballast is provided.

1.14. EQUIPMENT CHECKLIST.

The weight, arms, and moments for removable items of equipment are listed in the LLRV equipment checklist, Table 1-8. When items are permanently removed from the vehicle, they should be deleted from the checklist. New items which are permanent installations should be added to the checklist. When check marks are entered in the "ON VEHICLE" column, they serve as the inventory of equipment included in the basic weight. Inventories should be made periodically, but are required specifically when:

(a) The vehicle undergoes modification, major overhaul, or repair.

(b) Changes in equipment are made for a different type of operation or mission.

(c) The vehicle is reweighed.

Make certain that the same date is entered over the "CHECK" heading in the LLRV equipment checklist and in the date column on the basic weight and balance record (Paragraph 2.5.7) for the corresponding corrected basic weight and centers of gravity.

TABLE 1-6

HYDROGEN PEROXIDE IN TANKS

TOTAL LOADED* WEIGHT POUNDS (TWO TANKS) W	VOLUME U.S. GALLONS (TWO TANKS)	ARM** INCHES x	MOMENT POUND-INCHES Wx	ARM** INCHES y	MOMENT POUND-INCHES Wy	ARM** INCHES z	MOMENT POUND-INCHES Wz
670	57.8	200.0	134,000	200.0	134,000	200.0	134,000
650	56.0	200.0	130,000	200.0	130,000	199.8	129,854
625	53.9	200.0	125,000	200.0	125,000	199.4	124,616
600	51.7	200.0	120,000	200.0	120,000	199.0	119,415
575	49.6	200.0	115,000	200.0	115,000	198.6	114,209
550	47.4	200.0	110,000	200.0	110,000	198.3	109,090
525	45.2	200.0	105,000	200.0	105,000	198.0	103,963
500	43.1	200.0	100,000	200.0	100,000	197.7	98,863
475	40.9	200.0	95,000	200.0	95,000	197.4	93,767
450	38.8	200.0	90,000	200.0	90,000	197.1	88,706
425	36.6	200.0	85,000	200.0	85,000	196.8	83,651
400	34.5	200.0	80,000	200.0	80,000	196.5	78,594
375	32.3	200.0	75,000	200.0	75,000	196.2	73,562
350	30.2	200.0	70,000	200.0	70,000	195.8	68,542
325	28.0	200.0	65,000	200.0	65,000	195.5	63,546
300	25.9	200.0	60,000	200.0	60,000	195.2	58,553
275	23.7	200.0	55,000	200.0	55,000	194.8	53,580
250	21.6	200.0	50,000	200.0	50,000	194.5	48,631
225	19.4	200.0	45,000	200.0	45,000	194.1	43,678
200	17.2	200.0	40,000	200.0	40,000	193.8	38,755
175	15.1	200.0	35,000	200.0	35,000	193.4	33,849
150	12.9	200.0	30,000	200.0	30,000	193.0	28,948
125	10.8	200.0	25,000	200.0	25,000	192.5	24,066
100	8.6	200.0	20,000	200.0	20,000	192.0	19,202
75	6.5	200.0	15,000	200.0	15,000	191.5	14,364
50	4.3	200.0	10,000	200.0	10,000	191.0	9,551
25	2.2	200.0	5,000	200.0	5,000	190.2	4,756

*Table based on 90 percent H_2O_2 at 11.60 pounds per U.S. gallon at 70 degrees F.
**Vehicle in level attitude

TABLE 1-7

HYDROGEN PEROXIDE IN LINES

TOTAL WEIGHT W POUNDS	VOLUME U.S. GALLONS	ARM* x INCHES	MOMENT Wx POUND-INCHES	ARM* y INCHES	MOMENT Wy POUND-INCHES	ARM* z INCHES	MOMENT Wz POUND-INCHES

*Vehicle in level attitude.

TABLE 1-8

LLRV EQUIPMENT CHECKLIST

DATE

VEHICLE NO.

LOCATION AND ITEM NUMBER	DESCRIPTION AND PART NUMBER		WEIGHT POUNDS W	ARM INCHES x	MOMENT POUND-INCHES Wx	ARM INCHES y	MOMENT POUND-INCHES Wy	ARM INCHES z	MOMENT POUND-INCHES Wz	CHECK NUMBERS 1 ON VEHICLE	1 FORM II-5 ENTRY	2 ON VEHICLE	2 FORM II-5 ENTRY	3 ON VEHICLE	3 FORM II-5 ENTRY	4 ON VEHICLE	4 FORM II-5 ENTRY	5 ON VEHICLE	5 FORM II-5 ENTRY	6 ON VEHICLE	6 FORM II-5 ENTRY	7 ON VEHICLE	7 FORM II-5 ENTRY
A	PILOTS PLATFORM																							
A-1	Cockpit Enclosure, Windshield, 7161-150003-47		9.7	91.0	883	200.0	1940	222.7	2160															
A-2	Cockpit Enclosure Door, LH 7161-150003-29		4.7	115.7	544	176.8	831	227.0	1067															
A-3	Cockpit Enclosure Door RH 7161-150003-30		4.7	115.7	544	223.2	1049	227.0	1067															
A-4 ⚠1	Ejection Seat, Weber, 802900		99.2	125.4	12,438	200.0	19,838	209.7	20,800															
A-5	Parachute		20.0																					
A-6	Rocket Catapult		18.3																					
A-7 ⚠1	Instrument Panel, 7161-561001		38.0	90.8	3451	197.7	7515	213.6	8119															
A-8	Indicator, Normal Acceleration		1.7	91.0	155	196.4	334	214.0	364															
A-9	Indicator, Drift and Heading		3.3	91.0	300	200.0	660	219.2	723															
A-10	Indicator, Vertical Velocity		1.7	91.0	155	203.9	347	214.0	364															
A-11	Sensitive Altimeter		1.7	91.0	155	205.1	349	214.0	364															
A-12	Attitude Indicator, 4060-C		8.5	91.0	774	200.0	1700	213.3	1813															
A-13	Clock, AN5743-2		0.8	91.0	73	196.2	157	220.6	176															
A-14	Tachometer, Indicator, 8DJ81-AAA		0.8	91.0	73	189.4	152	220.5	176															
A-15	E.G.T. Indicator, 1121		0.8	91.0	68	191.7	144	220.5	165															
A-16	Indicator, Pressure, H_2O_2 Tank		1.2	91.0	109	189.4	227	214.9	258															
A-17	Indicator, Pressure Lift Rocket Chamber		1.2	91.0	109	191.7	230	214.9	258															
A-18	Indicator, Pressure, Helium Source		1.2	91.0	109	190.7	229	212.0	254															
A-19	Coarse Altimeter, 450610		0.6	91.0	53	204.4	118	220.1	128															
A-20																								
A-21																								
A-22																								
A-23 ⚠1	Console 7161-561002		9.3	109.7	1020	180.8	1681	198.9	1850															
A-24	Transmitter - Receiver, FM			104.1		181.6		201.5																
A-25	Throttle Quadrant 7161-435010-1		1.8	108.2	195	183.4	330	208.2	375															
A-26																								
A-27	Oxygen bottle, 5600-1C1-C4A		9.3	119.0	1110	213.0	1987	194.8	1817															
A-28	Force Gradient, 204-001-045-5	(2)	2.0	111.2	222	200.0	400	187.5	375															
A-29	Force Gradient, 204-001-045-7	(1)	1.0	83.5	84	196.3	196	187.4	187															
A-30 ⚠2	Camera																							

√ = On Vehicle
O = Not on Vehicle
X = Not Applicable to this Vehicle

⚠1 Including Subsequent Indented Items
⚠2 NASA Payload Item

TABLE 1-8. (CONT)
LLRV EQUIPMENT CHECKLIST

DATE

LOCATION AND ITEM NUMBER	DESCRIPTION AND PART NUMBER		WEIGHT POUNDS W	ARM INCHES x	MOMENT POUND-INCHES Wx	ARM INCHES y	MOMENT POUND-INCHES Wy	ARM INCHES z	MOMENT POUND-INCHES Wz	CHECK NUMBERS 1 ON VEHICLE	1 FORM II-5 ENTRY	2 ON VEHICLE	2 FORM II-5 ENTRY	3 ON VEHICLE	3 FORM II-5 ENTRY	4 ON VEHICLE	4 FORM II-5 ENTRY	5 ON VEHICLE	5 FORM II-5 ENTRY	6 ON VEHICLE	6 FORM II-5 ENTRY	7 ON VEHICLE	7 FORM II-5 ENTRY
VEHICLE NO.																								
B	CENTERBODY																							
B-1	Valve, Lift Control 7161-472060-1		5.8	157.8	907	200.0	1150	204.0	1173															
B-2	Valve, Emergency Lift Control, 7161-472080-1	(2)	4.9	153.9	751	200.0	976	204.0	996															
B-3	Check Valve, LH 7161-472045-1		1.5	146.0	219	188.5	283	209.4	314															
B-4	Check, Valve, R4 7161-472045-1		1.5	146.0	219	211.5	317	209.4	314															
B-5	Attitude Rocket Cluster, LH Fwd	(4)	6.4	130.0	832	163.8	1048	200.0	1280															
B-6	Attitude Rocket Cluster, RH Fwd	(4)	6.4	130.0	832	236.2	1512	200.0	1280															
B-7	Attitude Rocket Cluster, LH Rear	(4)	6.4	270.0	1728	163.8	1048	200.0	1280															
B-8	Attitude Rocket Cluster, RH Rear	(4)	6.4	270.0	1728	236.2	1512	200.0	1280															
B-9	Solenoid Valve, LH Fwd 7161-472075	(4)	3.3	130.0	426	168.0	551	200.0	656															
B-10	Solenoid Valve, RH Fwd 7161-472075	(4)	3.3	130.0	426	232.0	761	200.0	656															
B-11	Solenoid Valve, LH Rear 7161-472075	(4)	3.3	270.0	886	168.0	551	200.0	656															
B-12	Solenoid Valve, RH Rear 7161-472075	(4)	3.3	270.0	886	232.0	761	200.0	656															
B-13	Variable Orifice, LH Fwd, 7161-472110	(4)	3.5	130.0	458	174.8	615	200.0	704															
B-14	Variable Orifice, RH Fwd 7161-472110	(4)	3.5	130.0	458	225.2	793	200.0	704															
B-15	Variable Orifice, LH Rear 7161-472110	(4)	3.5	270.0	950	174.8	615	200.0	704															
B-16	Variable Orifice, RH Rear 7161-472110	(4)	3.5	270.0	950	225.2	793	200.0	704															
B-17	Shutoff Valve Electric, LH, 7161-472040		3.7	173.4	645	172.8	643	204.0	759															
B-18	Shutoff Valve Electric, RH, 7161-472040		3.7	173.5	645	227.2	845	204.0	759															
B-19	Valve, Motor Operated, Forward 7161-472055		1.3	153.0	199	200.0	260	208.0	270															
B-20	Valve, Motor Operated, Forward 7161-472055		1.3	153.0	199	200.0	260	216.0	281															
B-21	Helium Pressure Regulator 7161-472015	(2)	4.2	222.4	943	200.0	848	198.0	840															
B-22	Thrust Chamber, Lift, Normal 7161-470001 LH		7.4	200.0	1472	166.0	1222	192.5	1417															
B-23	Thrust Chamber, Lift, Normal 7161-470001 RH		7.4	200.0	1472	234.0	1722	192.5	1417															
B-24	Check Valve, 7161-472070	(2)	3.0	178.0	534	200.0	600	196.7	590															
B-25	Plenum Tank, 7161-471020, LH		1.3	219.2	289	166.0	219	207.0	273															
B-26	Plenum Tank, 7161-471020, RH		1.3	219.2	289	234.0	309	207.0	273															
B-27	Relief Valve, 7161-472030 LH		2.8	219.0	613	161.0	451	220.0	616															
B-28	Relief Valve, 7161-472030 RH		2.8	219.0	613	239.0	669	220.0	616															
B-29	Thrust Chamber 500 lb Emergency LH 7161-470001	(3)	22.1	205.0	4532	167.0	3692	192.5	4256															
B-30	Thrust Chamber 500 lb Emergency RH 7161-470001	(3)	22.1	195.0	4311	233.0	5152	192.5	4256															
B-31																								
B-32	Actuator, Pitch 7161-390001-1		8.8	190.5	1678	232.9	2052	204.8	1804															

TABLE 1-8. (CONT)
LLRV EQUIPMENT CHECKLIST

VEHICLE NO.									DATE																	
									CHECK NUMBERS																	
									1		2		3		4		5		6		7					
LOCATION AND ITEM NUMBER	DESCRIPTION AND PART NUMBER		WEIGHT POUNDS W	ARM INCHES x	MOMENT POUND-INCHES Wx	ARM INCHES y	MOMENT POUND-INCHES Wy	ARM INCHES z	MOMENT POUND-INCHES Wz	ON VEHICLE	FORM II-5 ENTRY	ON VEHICLE	FORM II-5 ENTRY	ON VEHICLE	FORM II-5 ENTRY	ON VEHICLE	FORM II-5 ENTRY	ON VEHICLE	FORM II-5 ENTRY	ON VEHICLE	FORM II-5 ENTRY	ON VEHICLE	FORM II-5 ENTRY	ON VEHICLE	FORM II-5 ENTRY	ON VEHICLE	FORM II-5 ENTRY
B	CENTERBODY (Continued)																									
B-33	Actuator, Roll 7161-390001-1		8.8	174.1	1534	209.9	1849	195.6	1723																	
B-34	Accumulator MS 28700-2		5.4	170.6	926	200.0	1086	203.1	1103																	
B-35	Valve, 3 Way 60600-4		1.3	186.0	242	227.1	295	202.5	263																	
B-36	Fuel Flow Proportioner, 25990-1		2.20	221.5	487	171.6	378	205.0	451																	
B-37	Accelerometer Installation, RH, 7161-561004		1.7	200.0	330	237.6	392	200.0	330																	
B-38	Accelerometer Installation, LH, 7161-561004		1.7	200.0	330	162.4	268	200.0	330																	
B-39	Accelerometer Installation, Aft, 7161-561004		1.7	238.0	314	200.0	348	200.0	348																	
C	REAR PLATFORM, FIXED																									
C-1	Drogue Chute, 7161-264002-1, Less bridles		15.0	275.0	4125	215.0	3225	230.5	3458																	
C-2	Chute Bridles Stowed	(4)	3.9	257.1	1008	208.2	816	229.3	899																	
C-3	Helium Tank, LH 7161-471002, Empty		22.3	270.0	6010	191.5	4263	191.5	4263																	
C-4	Helium Tank, RH 7161-471002, Empty		22.3	270.0	6010	208.5	4641	191.5	4263																	
C-5	Helium Gas, LH			270.0		191.5		191.5																		
C-6	Helium Gas, RH			270.0		208.5		191.5																		

TABLE 1-8. (CONT)
LLRV EQUIPMENT CHECKLIST

DATE

VEHICLE NO.

LOCATION AND ITEM NUMBER	DESCRIPTION AND PART NUMBER	WEIGHT POUNDS W	ARM INCHES x	MOMENT POUND-INCHES Wx	ARM INCHES y	MOMENT POUND-INCHES Wy	ARM INCHES z	MOMENT POUND-INCHES Wz	CHECK NUMBERS 1 ON VEHICLE	1 FORM II-5 ENTRY	2 ON VEHICLE	2 FORM II-5 ENTRY	3 ON VEHICLE	3 FORM II-5 ENTRY	4 ON VEHICLE	4 FORM II-5 ENTRY	5 ON VEHICLE	5 FORM II-5 ENTRY	6 ON VEHICLE	6 FORM II-5 ENTRY	7 ON VEHICLE	7 FORM II-5 ENTRY
D	REAR PLATFORM, MOVABLE (3)																					
D-1	Avionics Rack Structure, 17-09680	13.6	325.9	4432	193.4	2630	223.6	3041														
D-2	Power Amplifier 17-09550-1	8.3	325.6	2702	187.7	1558	218.4	1813														
D-3	Weight and Drag Computer 17-09570-1	6.8	325.6	2214	198.5	1350	233.7	1589														
D-4	Monitor 17-09590-1	12.1	325.6	3950	197.1	2391	226.2	2744														
D-5	Auto Throttle 17-09500-1	5.9	326.6	1927	186.4	1100	226.2	1334														
D-6	Input and Summation 17-09580-1	10.0	325.6	3256	197.3	1973	218.7	2187														
D-7	ACS Adjustment Potentiometer Package, 17-09610-1	4.4	329.6	1450	197.2	868	211.0	928														
D-8	Transformer 17-09539-1	1.0	325.0	325	184.8	185	209.4	209														
D-9	Emergency Inverter	7.6	323.0	2455	186.0	1414	209.0	1588														
D-10	Gyro Package, 17-09720	19.6	277.0	5429	191.0	3744	209.8	4112														
D-11	Jet Stab Amplifier 17-09520-1	11.1	325.6	3614	188.7	2094	233.7	2594														
D-12	Battery, 7161-202002-1	6.0	314.3	1886	187.5	1125	226.0	1356														
D-13	Voltage Regulator CSV-1178-1	1.9	314.4	604	195.5	375	224.0	430														
D-14	Power Shield 7161-203001-1	2.8	315.2	879	191.0	533	220.5	615														
D-15																						
D-16																						
D-17 (2)	PCM Telemetry Transmitter	15.0	320.0	4800	214.0	3210	211.5	3173														
D-18 (2)	DC Signal Conditioner	7.0	314.0	2198	211.0	1477	211.0	1477														
D-19 (2)	AC Signal Conditioner	6.0	314.0	1884	216.0	1296	211.0	1266														
D-20 (2)	Power Supply	7.0	316.0	2212	207.0	1449	211.0	1477														
D-21 (2)	Radar Altimeter Control	9.2	314.5	2893	191.0	1757	211.5	1946														
D-22 (2)	Radar Altimeter Transmitter	5.6	314.0	1758	210.0	1176	199.0	1114														
D-23 (2)	Radar Altimeter Receiver	2.9	328.5	953	210.0	609	200.0	580														
D-24 (2)	Radar Altimeter Data Converter	2.0	326.5	653	208.5	417	209.0	418														
D-25 (2)	Doppler Receiver Transmitter	13.3	326.0	4320	191.0	2531	198.0	2624														
D-26 (2)	Doppler Converter	22.0	320.0	7040	203.0	4466	211.0	4642														

(3) All centers of gravity are with the movable items in the full down, full aft, central position
(2) NASA payload item.

TABLE 1-8. (CONT)
LLRV EQUIPMENT CHECKLIST

DATE

LOCATION AND ITEM NUMBER	DESCRIPTION AND PART NUMBER	WEIGHT POUNDS W	ARM INCHES x	MOMENT POUND-INCHES Wx	ARM INCHES y	MOMENT POUND-INCHES Wy	ARM INCHES z	MOMENT POUND-INCHES Wz	CHECK NUMBERS 1 ON VEHICLE	1 FORM II-5 ENTRY	2 ON VEHICLE	2 FORM II-5 ENTRY	3 ON VEHICLE	3 FORM II-5 ENTRY	4 ON VEHICLE	4 FORM II-5 ENTRY	5 ON VEHICLE	5 FORM II-5 ENTRY	6 ON VEHICLE	6 FORM II-5 ENTRY	7 ON VEHICLE	7 FORM II-5 ENTRY
VEHICLE NO.																						
E	GIMBAL RING AND POWER PLANT (6)																					
E-1	Compressor Inlet 7161-421036	5.6	199.6	1092	199.6	1093	230.7	1264														
E-2	Engine, CF 700-2V, Basic Dry	628.0	199.7	125,412	199.0	124,972	197.6	124,093														
E-3	Generator DGH-245-1	30.7	205.7	6315	188.1	5775	226.2	6944														
E-4	Inverter 1518-8-B	33.0	205.2	6764	212.0	6992	212.6	7012														
E-5	Reverse Current Relay AN3025-300	2.7	211.0	579	188.2	517	214.0	588														
E-6	Tachometer 7161-434012-1	0.8	196.5	157	188.1	150	210.2	168														
E-7	Auto Throttle Control 17-08250-1	6.9	186.7	1292	191.5	1325	214.7	1486														
E-8	Hydraulic Pump 7161-390002-1	1.8	205.6	370	188.1	338	214.0	385														
E-9	Hydraulic Reservoir 7161-390003-1	1.5	212.3	319	188.1	282	220.0	330														
E-10	Hydraulic Fluid (Reservoir Full)	3.0	212.3	637	188.2	565	220.0	660														
E-11	Hydraulic Filter MS28896-4	0.8	217.0	163	193.8	145	186.8	140														
E-12 (4)	Gimbal Lock - Pitch																					
E-13 (4)	Gimbal Lock - Roll																					
E-14 (2)	Screen - Compressor Inlet 7161-880002																					
E-15 (2)	Screen - Fan Inlet 7161-880003																					
E-16 (4)	Cover, Compressor Inlet, 7161-880007-1	2.9	200.0	580	200.0	580	235.0	682														
E-17 (4)	Cover, Fan Inlet, 7161-880001-3,5,7, and 9 (4)	6.1	200.0	1220	200.0	1220	201.0	1226														

(6) All centers of gravity are with the engine vertical and exerting 1g thrust.
(2) NASA payload item.
(4) Ground support equipment.

TABLE 1-8. (CONT)
LLRV EQUIPMENT CHECKLIST

DATE

VEHICLE NO.									CHECK NUMBERS															
									1		2		3		4		5		6		7			
LOCATION AND ITEM NUMBER	DESCRIPTION AND PART NUMBER	WEIGHT POUNDS W	ARM INCHES x	MOMENT POUND-INCHES Wx	ARM INCHES y	MOMENT POUND-INCHES Wy	ARM INCHES z (5)	MOMENT POUND-INCHES Wz	ON VEHICLE	FORM II-5 ENTRY	ON VEHICLE	FORM II-5 ENTRY	ON VEHICLE	FORM II-5 ENTRY	ON VEHICLE	FORM II-5 ENTRY	ON VEHICLE	FORM II-5 ENTRY	ON VEHICLE	FORM II-5 ENTRY	ON VEHICLE	FORM II-5 ENTRY		
F	TRUSS LEGS AND MISCELLANEOUS																							
F-1	Fuel Tank Assy Fwd 7161-424017-1	16.0	146.1	2336	200.0	3198	188.0	3006																
F-2	Fuel Tank Assy, Aft 7161-424017-1	16.0	253.9	4059	200.0	3198	212.0	3390																
F-3	Hydrogen Peroxide Tank, LH, 7161-471001	35.8	200.0	7164	148.5	5319	200.0	7164																
F-4	Hydrogen Peroxide Tank, RH, 7161-471001	35.8	200.0	7164	251.5	9009	200.0	7164																
F-5 (1)	Strut Installation, LH Forward, 7161-191005-1	34.9	119.9	4185	119.9	4185	141.1	4926																
F-6	Strut, 7161-191006-1	20.0	119.9	2397	119.9	2397	145.4	2908																
F-7	Pad 7161-191002-1	2.3	119.9	279	119.9	279	117.0	273																
F-8 (4)	Caster Assy LH Forward 7161-191005-5	24.6	119.9	2949	119.9	2949	111.4	2741																
F-9 (1)	Strut Installation, LH Rear, 7161-191005-1	34.9	280.1	9783	119.9	4185	141.1	4926																
F-10	Strut, 7161-191006-1	20.0	280.1	5603	119.9	2397	145.4	2908																
F-11	Pad 7161-191002-1	2.3	280.1	653	119.9	279	117.0	273																
F-12 (4)	Caster Assy LH Rear 7161-191005-5	24.6	280.1	6894	119.9	2949	111.4	2741																
F-13 (1)	Strut Installation RH Forward 7161-191005-1	34.9	119.9	4185	280.1	9783	141.1	4926																
F-14	Strut, 7161-191006-1	20.0	119.9	2397	280.1	5603	145.4	2908																
F-15	Pad 7161-191002-1	2.3	119.9	279	280.1	653	117.0	273																
F-16 (4)	Caster Assy RH Forward 7161-191005-5	24.6	119.9	2949	280.1	6894	111.4	2741																
F-17 (1)	Strut Installation, RH Rear 7161-191005-1	34.9	280.1	9783	280.1	9783	141.1	4926																
F-18	Strut 7161-191006-1	20.0	280.1	5603	280.1	5603	145.4	2908																
F-19	Pad 7161-191002-1	2.3	280.1	653	280.1	653	117.0	273																
F-20 (4)	Caster Assy RH Rear 7161-191005-5	24.6	280.1	6894	280.1	6894	111.4	2741																
F-21	External Power Receptacle, RH Forward 7161-200009	0.6	183.8	110	242.6	146	186.5	112																

(1) Including subsequent indented items.
(5) Centers of gravity with strut at full extension.
(4) Ground support equipment.

SECTION II

ACTUAL WEIGHING DATA

2.1. GENERAL INFORMATION.

Weighing of this vehicle is accomplished in four separate operations. Extreme care must be taken in measuring the actual weight and balance of the LLRV in order to assure that the CG limits discussed in Paragraph 1.3. are not exceeded. These operations include:

(a) Weight and center of gravity determination of the center of gravity fixture.

(b) Weight and vertical center of gravity determination of the jet engine assembly, gimbal ring,and associated equipment.

(c) Weight and horizontal center of gravity determination of the center of gravity fixture and gimballed equipment.

(d) Weight and center of gravity determination of the complete vehicle mounted on the center of gravity fixture.

2.2. WEIGHT AND CENTER OF GRAVITY DETERMINATION OF THE CENTER OF GRAVITY FIXTURE.

2.2.1. Description. - The LLRV Center of Gravity Fixture, part number 7161-700001, is shown in Figure 2-1. The fixture consists of the following five major components and three sets of attachment hardware.

2.2.1.1. Major Components. -

Support truss assembly (one)

Weighing scales (three, not supplied)

Engine mount plates (three)

Master ring (one)

Spacers (three)

2.2.1.2. Support Truss Assembly. - The support truss assembly consists of a reinforced triangular base plate 95 inches long and 109 inches wide to which are attached three eight-inch diameter swivelling casters. The base plate provides a support for three 1-3/4-inch diameter adjustment screws and a tubular welded truss framework. The top of the truss framework is welded to a 46-1/4-inch diameter retaining ring having a depth of 3-3/4 inches. Permanently fastened to this ring are three welded mount fittings for attachment

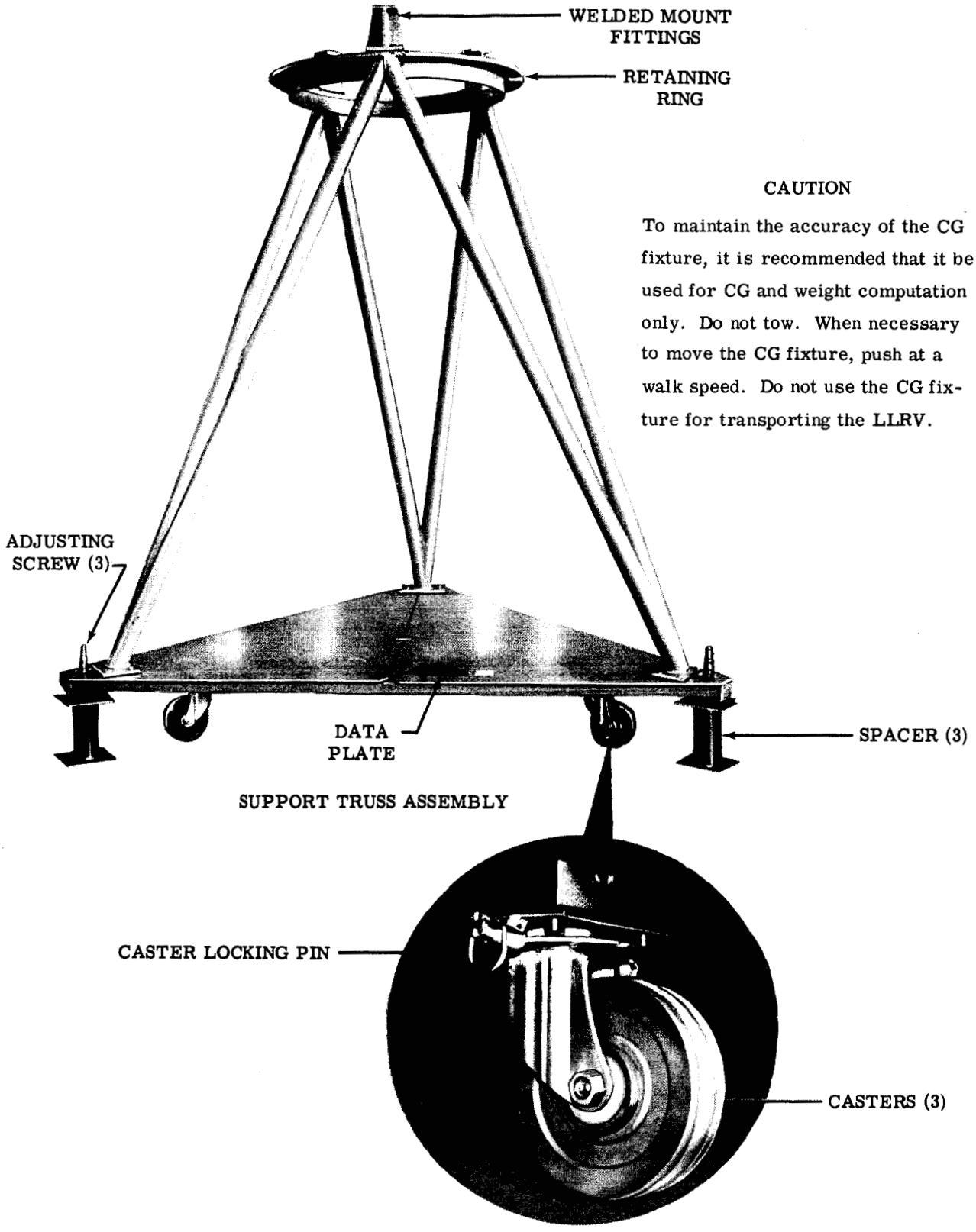


Figure 2-1. Center of Gravity Fixture

of the LLRV. These fittings are six inches square at the base, four inches square at the top with a height of eight inches. The 3/4-inch thick top plates of the fittings are drilled for attachment bolts and are machined so that their top surfaces lie in one plane.

The overall dimensions of the support truss assembly are length, 95 inches; width, 109 inches; and height, 119 inches. The weight is approximately 1000 pounds.

2.2.1.3. Engine Mount Plates - The engine mount plates, shown in Figure 2-2, are to be attached to the LLRV engine mount at three points and are employed to adapt and position the vehicle on the center of gravity fixture. The plates are three inches square and 3/4 inch thick with four 5/16-inch holes and one 1/2-inch tapped hole for attachment bolts. A 5/8-inch diameter centering pin is also provided in each plate.

2.2.1.4. Master Ring. - The master ring, shown in Figure 2-3, is employed as a template to accurately position the engine mount plates with respect to the main engine mounts. It is also used during fixture assembly to accurately locate the mount fittings of the support truss assembly. The master ring is fabricated of 1/2-inch aluminum plate with an outside diameter of 56 inches and an inside shape contoured for clearance with the LLRV engine. Two tangs are provided on the inside of this ring for attachment to the unused main mounts of the LLRV jet engine. Three accurately located 5/8-inch inside diameter bushings are provided for positioning the three engine mount plates. Two captive 7/16-inch diameter bolts are provided for attaching the ring to the main engine mounts. Identification notes are provided on the master ring to indicate the correct installation directions.

2.2.1.5. Spacers. - Three 10-1/4-inch high spacers are provided to adapt the fixture to a flush mounted floor scale installation.

2.2.1.6. Attachment Hardware. -

Master ring attachment pins (two, part number 7161-421028-1)

Engine mount plate attachment bolts (twelve, NAS674-16H)

LLRV mounting screws (four, 1/2-inch diameter socket head cap screws with warning streamers)

2.2.2. Procedure. -

Step 1. Obtain three scales of at least 500-pound capacity and accurate within ±0.25 pound. Ensure that the scales are correctly calibrated and levelled. Establish scale zero errors.

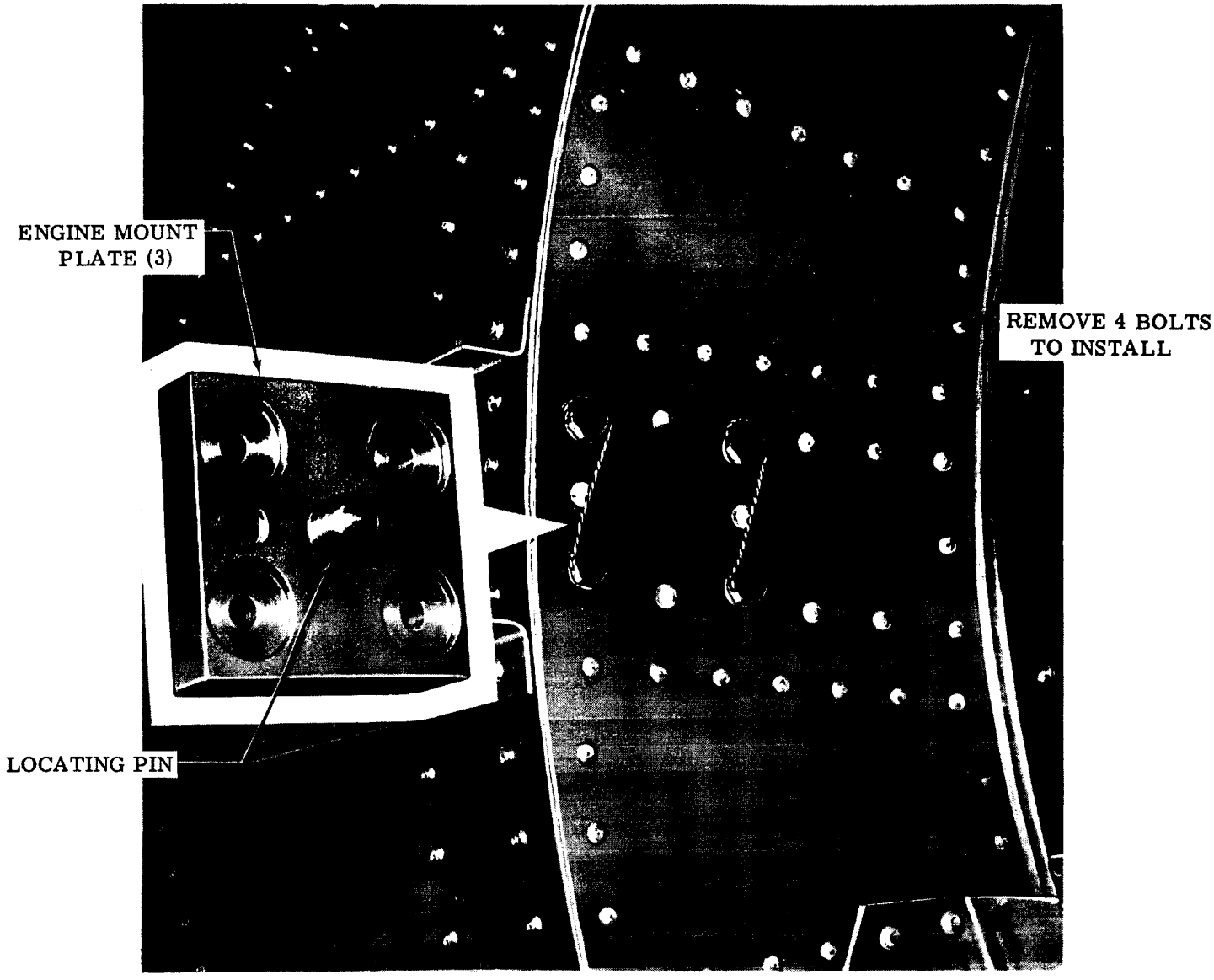
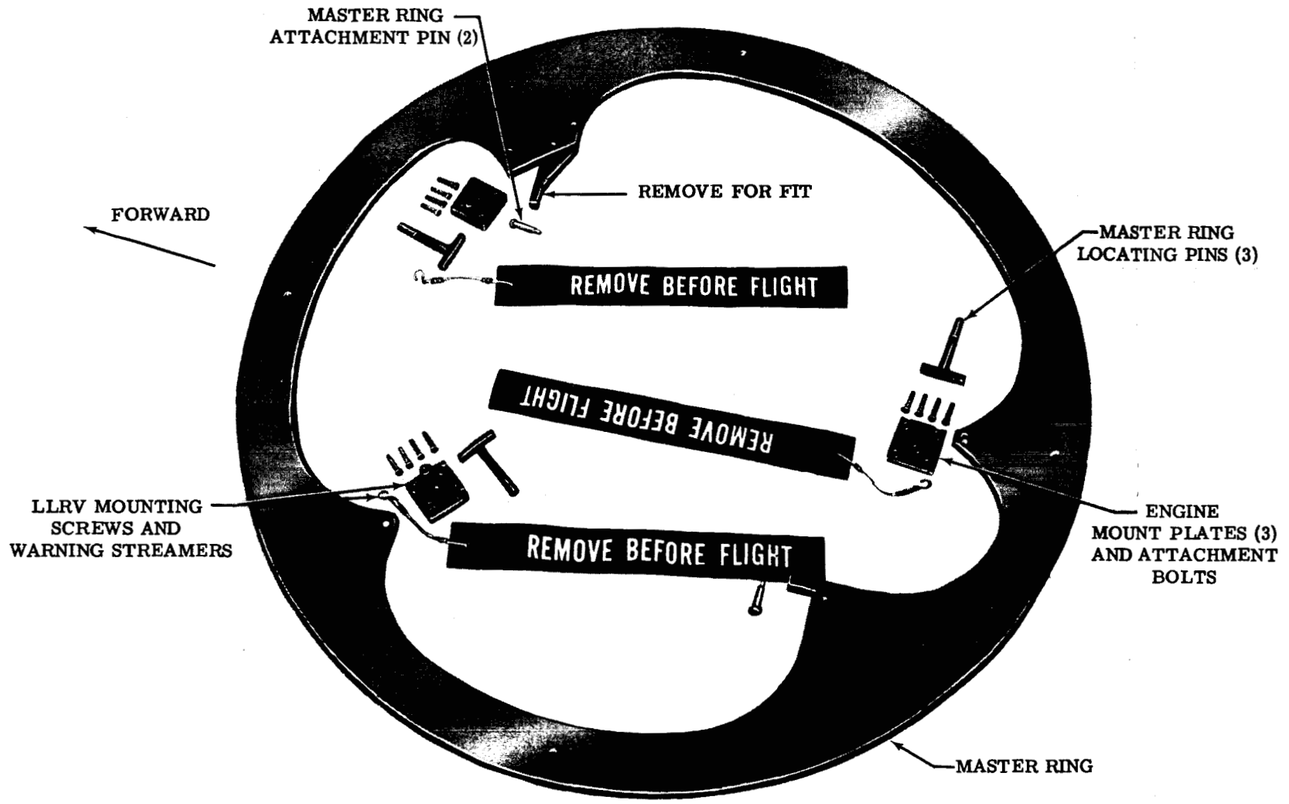


Figure 2-2. Engine Mounting Detail



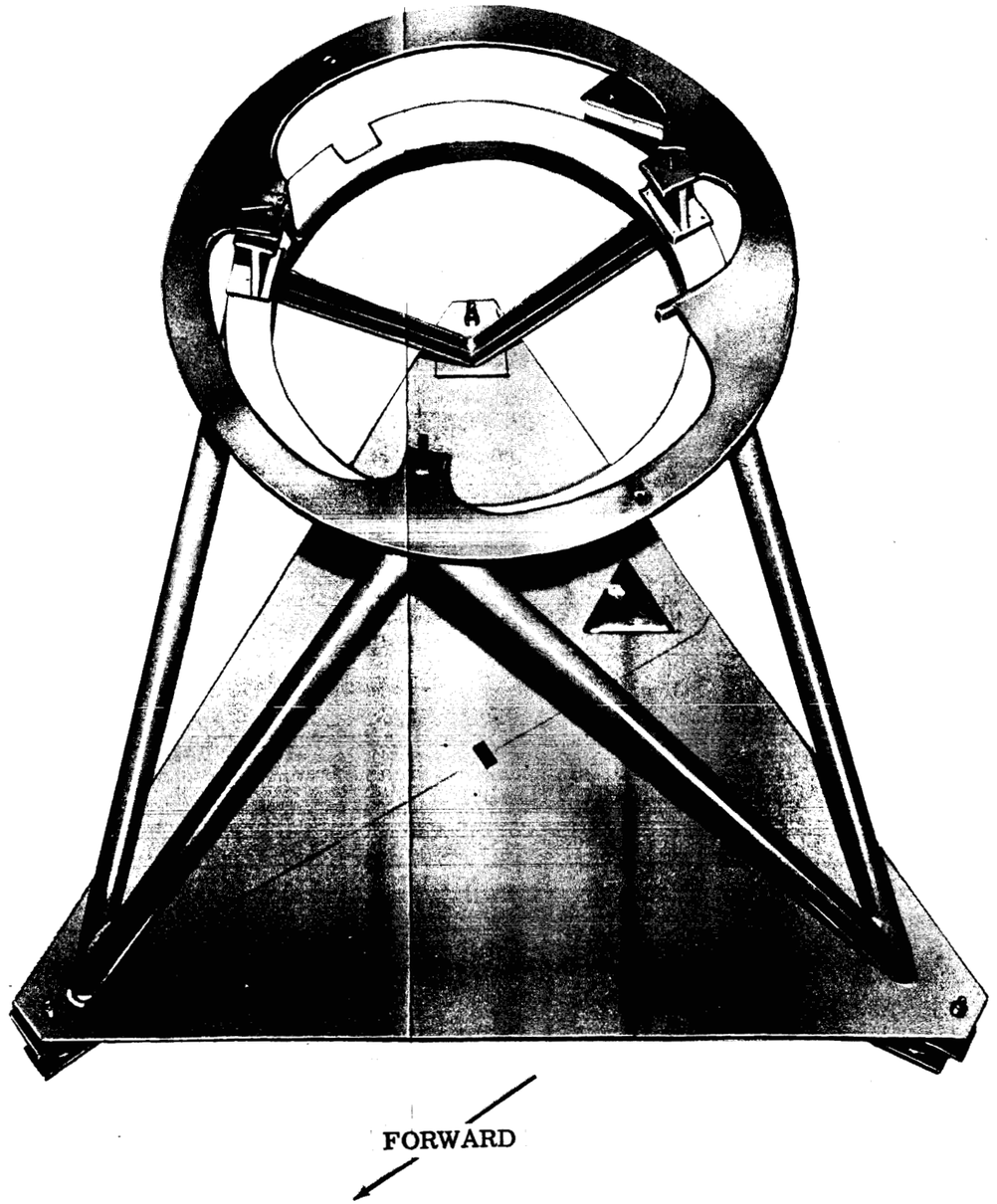


Figure 2-3. Master Ring

Step 2. Position the three scales under the 1-3/4-inch adjusting screws, located at each corner of the support truss assembly triangular base. Scales should be located so that the adjusting screws are as close as possible to the center of the weighing platform.

NOTE

When a flush scale installation is used, it will be necessary to position the support truss assembly over the platforms, then locate the 10-1/4-inch spacers under the adjusting screws.

Step 3. Transfer the weight of the support truss assembly from the casters to the weighing scales by turning the adjusting screws. Lock the support truss assembly casters.

CAUTION

The casters must be locked in the same position for each weighing exercise to insure consistent results.

Step 4. Loosely attach the engine mount plates to the engine mount fittings using the NAS674-16H bolts. Loosely install the three 1/2-inch diameter socket head cap screws with warning streamers.

NOTE

This hardware is required to attach the engine mount to the fixture and is not part of the vehicle. Its weight must therefore be included with that of the center of gravity fixture.

Step 5. Level the support truss assembly in the lateral and longitudinal planes using the adjustment screws and a clinometer applied to the top support ring fittings. Access to the fittings will require a ladder or a maintenance stand.

NOTE

A Hilger and Watts No. 75022 Clinometer or its equivalent having an accuracy of ±5.0 minutes is recommended.

Step 6. Record scale readings on Weighing Record Form II-1, sheet 1.

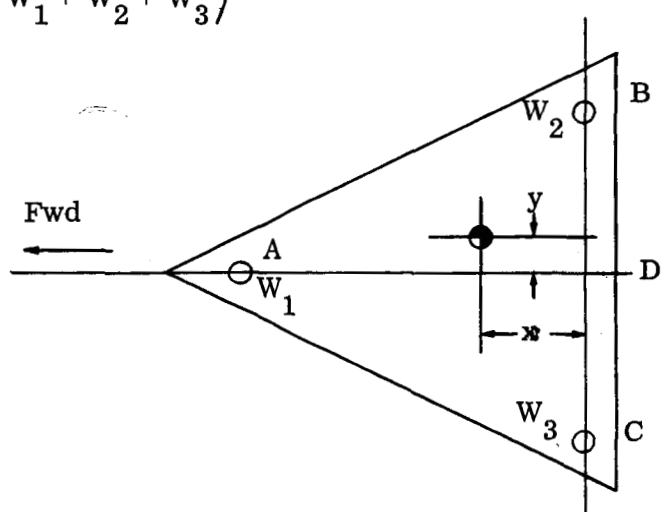
Step 7. Unlock the casters. Transfer the weight of the fixture from the scales to the casters by turning the adjustment screws. Remove the platform scales or the 10-1/4-inch spacers if a flush weighing facility is used, and move the fixture off the platforms. Recheck the scales for zero errors. Record all results as required using the Weighing Record Form II-1.

Step 8. As a check on accuracy, repeat Steps 2, 3, 5, and 6. The fixture should be rotated so that each leg now stands on a different scale. Upset the beam on each scale and take the mean of several readings. When the weight and center of gravity of the fixture are obtained, they should be marked on the fixture for permanent reference.

Step 9. Locate the fixture center of gravity by taking moments. (See diagram and Weighing Record Form II-1, sheets 1 and 2.)

$$x = \left(\frac{W_1 \times AD}{W_1 + W_2 + W_3} \right) \text{ inches}$$

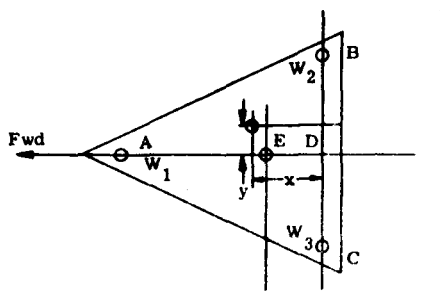
$$y = \left(\frac{W_2\, BD - W_3\, CD}{W_1 + W_2 + W_3} \right) \text{inches}$$



Dimensions AD, BD, and DC are inscribed on the fixture.

WEIGHING RECORD

CENTER OF GRAVITY FIXTURE

DATE	PLACE			WEIGHED BY
JACKPOINT	SCALE READING	TARE	NET WEIGHT	
A			W_1	
B			W_2	
C			W_3	
Total as Weighed				

MEASUREMENTS (Inscribed on fixture)

AD = _____ inches, the distance from jackpoint A to BC
BD = _____ inches, the distance from jackpoint B to AD
DC = _____ inches, the distance from jackpoint C to AD
ED = _____ inches, the distance from BC to the projected engine vertical centerline

CENTER OF GRAVITY CALCULATIONS

x = distance of center of gravity from BC
y = distance of center of gravity from AD

$$x = \left(\frac{W_1 \times AD}{W_1 + W_2 + W_3} \right) \text{ inches} = \_\_\_\_\_ \text{ inches}$$

$$y = \left[\frac{(W_2 \times BD) - (W_3 \times CD)}{W_1 + W_2 + W_3} \right] \text{ inches} = \_\_\_\_\_ \text{ inches}$$

WEIGHING RECORD

CENTER OF GRAVITY FIXTURE

Convert centers of gravity x and y to vehicle body stations X and buttock lines Y.

BS X = (200 + ED - x) inches = _____ inches

BL Y = (200 ± y) inches = _____ inches

Determine the correct sign for y by comparing the values of W_2 and W_3.

If $W_3 > W_2$, y is negative

If $W_2 > W_3$, y is positive

If $W_2 = W_3$, y is zero

2.3 WEIGHT AND VERTICAL CENTER OF GRAVITY DETERMINATION OF THE JET ENGINE ASSEMBLY, GIMBAL RING, AND ASSOCIATED EQUIPMENT.

2.3.1. General. - All items supported within the gimbal pitch bearings must be weighed and have their center of gravity determined before being installed in the vehicle. This procedure assumes that the jet engine is supported in a Model 3100 Air Logistics Workstand (Figure 2-4) or an equivalent parallel rail equipment.

2.3.2. Procedure. -

Step 1. Obtain a suitable set of calibrated scales and ensure that they are level. Establish scale zero errors. If platform scales are to be used, four, with a capacity of 300 to 500 pounds each will be required. Flush type floor scales are preferable and should be used if available.

Step 2. Ensure that the jet engine assembly is securely locked in the Supporting Frames (part number 7161-752002).

NOTE

The hydraulic reservoir and engine oil tank must be drained before the jet engine assembly is rotated into the horizontal position.

Step 3. Using the hoist rings provided, position the workstand on the scales. Check the attitude of the workstand by using a clinometer on the upper surface of the rail and shim under the legs to bring the stand to the level position within ±0.5 degree. Check the jet engine assembly attitude by using a clinometer on a suitable area of the casing. The power plant should be levelled to within ±0.5 degree.

Step 4. Note the scale readings. Obtain a mean of at least three readings, upsetting the beam between each reading.

Step 5. Immediately after weighing, measure the distances between the scale reaction points. On the four legged workstand, measure both sides and use the mean value. Using a plumb bob and tape measure (or other suitably accurate method), locate the jet engine assembly mounting lugs with respect to the

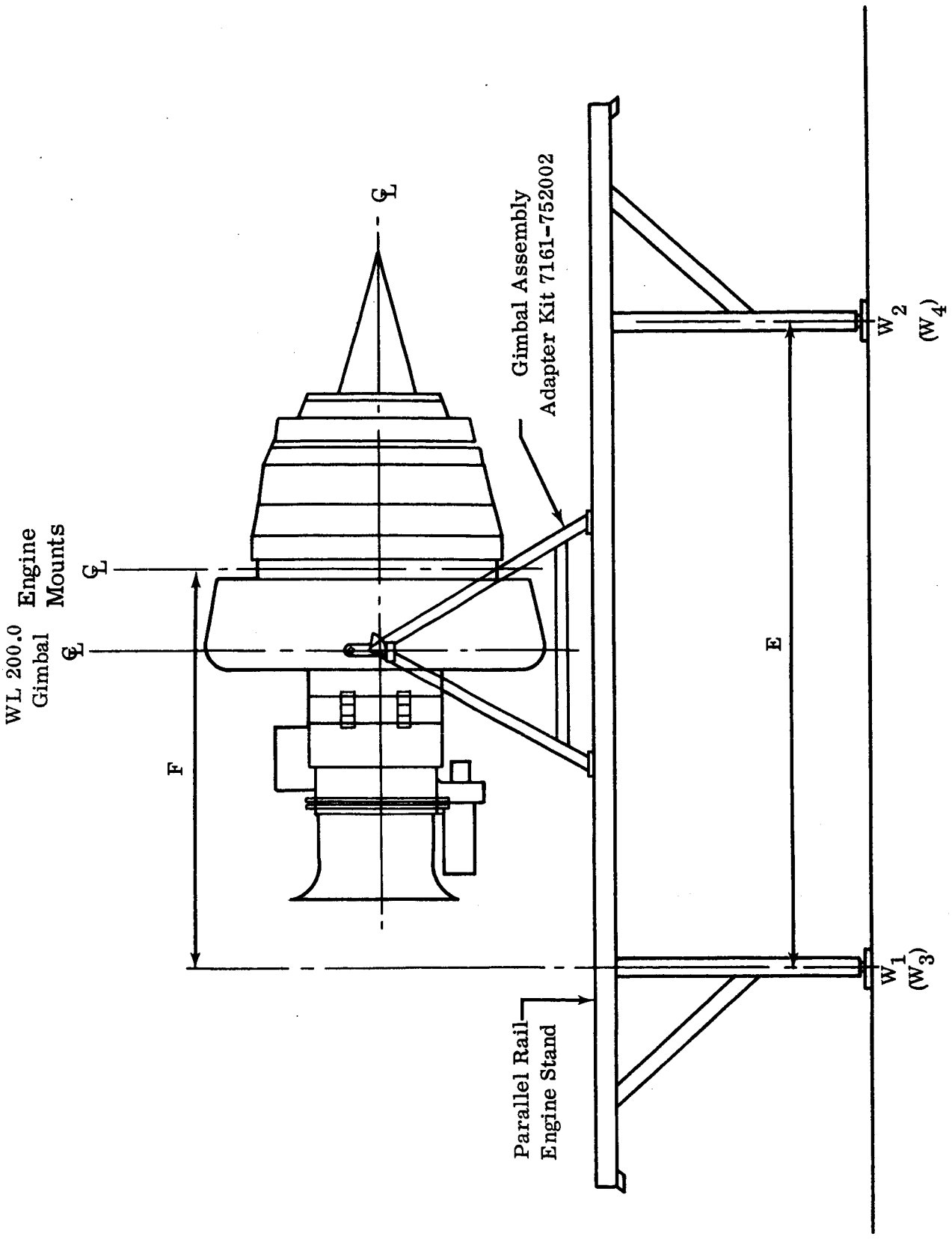


Figure 2-4. Jet Engine Assembly and Workstand

scale contact points. Determine the combined center of gravity of the jet engine assembly and workstand by taking moments.

Step 6. Repeat Steps 1 through 5 on the workstand and adapter kit. Remove the workstand from the scales and recheck for zero errors.

Step 7. By subtraction, obtain the weight and center of gravity of the jet engine assembly package. Convert the jet engine assembly center of gravity to a vehicle waterline value. (Refer to Bell Aerosystems Company's drawing No. 7161-421001.)

Step 8. Weigh the assembled gimbal ring. The center of gravity of this unit is at Station 200.0 in all three axes. Add the weight and moment of the gimbal ring to the jet engine assembly. Make whatever adjustments are necessary for missing or extra items and obtain the weight and center of gravity of the complete gimballed assembly. Record results for use when weighing the complete vehicle.

Step 9. Weighing Record Forms similar to Form II-2 should be used to facilitate computations.

WEIGHING RECORD

GIMBALLED EQUIPMENT

DATE	PLACE	WEIGHED BY

A. GIMBALLED EQUIPMENT AND WORKSTAND

ENGINE NO.	STAND NO.	TYPE OF SCALES USED
ENGINE ATTITUDE °	STAND ATTITUDE °	

REACTION	SCALE READING	TARE	NET WEIGHT
Fwd Leg A			W_1
Fwd Leg B			
Rear Leg C			W_2
Rear Leg D			
Total as Weighed			

MEASUREMENTS

E = _____ inches, the mean distance between scale reaction points

F = _____ inches, the distance between the engine mount centerline and forward scale reaction point

CENTER OF GRAVITY CALCULATIONS

x = distance of center of gravity from forward scale reaction point

$$x = \left(\frac{W_2 \times E}{W_1 + W_2} \right) \text{inches} = \_\_\_\_\_ \text{ inches}$$

WEIGHING RECORD

GIMBALLED EQUIPMENT

B. WORKSTAND AND ENGINE SUPPORTS

STAND ATTITUDE °	STAND NO.	SCALES USED

REACTION	SCALE READING	TARE	NET WEIGHT
Fwd Leg A			W_3
Fwd Leg B			
Rear Leg C			W_4
Rear Leg D			
Total as Weighed			

CENTER OF GRAVITY CALCULATIONS

y = distance of workstand center of gravity from forward scale reaction point

$$y = \left(\frac{E\ W_4}{W_3 + W_4} \right) \text{inches} = \_\_\_\_\_ \text{ inches}$$

z = distance of gimballed equipment center of gravity from forward scale reaction point.

$$z = \left(\frac{x\ (W_1 + W_2) - y\ (W_3 + W_4)}{(W_1 + W_2) - (W_3 + W_4)} \right) \text{inches} = \_\_\_\_\_ \text{ inches}$$

Weight of gimballed equipment = $(W_1 + W_2) - (W_3 + W_4)$ = _____ pounds.

Knowing distances F and z, convert the gimballed equipment center of gravity to vehicle waterline Z.

WEIGHING RECORD
GIMBALLED EQUIPMENT

C. BASIC WEIGHT AND VERTICAL CENTER OF GRAVITY OF GIMBALLED EQUIPMENT

COLUMN I				COLUMN II			
ITEMS WEIGHED BUT NOT PART OF BASIC GIMBALLED EQUIPMENT	WEIGHT POUNDS	VERT ARM Z INCHES	MOMENT WZ POUND-INCHES	BASIC ITEMS NOT ON GIMBALLED EQUIPMENT WHEN WEIGHED	WEIGHT POUNDS	VERT ARM Z INCHES	MOMENT WZ POUND-INCHES
Total				Total			

DESCRIPTION	NET WEIGHT POUNDS W	VERT ARM Z INCHES	MOMENT WZ POUND-INCHES
Total as Weighed $(W_1 + W_2)-(W_3 + W_4)$			
Engine Oil	+		+
Hydraulic Oil	+		+
Gimbal Ring	+		+
Total Col. I Items	-		-
Total Col. II Items	+		+
Basic Weight			

Enter this basic weight, arm, and moment in the Gimballed Equipment Basic Weight and Balance Record, Form II-4.

2.4 WEIGHT AND HORIZONTAL CENTER OF GRAVITY DETERMINATION OF THE CENTER OF GRAVITY FIXTURE, JET ENGINE ASSEMBLY, GIMBAL RING, AND ASSOCIATED EQUIPMENT.

2.4.1. Preparation for Weighing. -

Step 1. Determine the weight and lateral centers of gravity of the center of gravity fixture as described in Paragraph 2.2.

Step 2. Determine the weight and vertical center of gravity of the gimballed equipment as described in Paragraph 2.3.

Step 3. Obtain three suitable scales. Ensure that the scales are correctly calibrated and levelled.

Step 4. Position and level the fixture as described in Paragraph 2.2.2., Steps 2 through 5.

Step 5. Note scale readings and compare with figures obtained when the fixture was last weighed. If there is a discrepancy, determine the cause and rectify before proceeding.

2.4.2 Procedure for Positioning the Jet Engine Assembly on the Center of Gravity Fixture.-

Step 1. Turn the engine to the vertical position in the workstand. Service the oil and hydraulic systems if necessary.

Step 2. Using an overhead hoist, lower the Vertical Sling Assembly, Part Number 7161-753001-1, over the engine. Remove four pins, Part Number VP9STS5S17T5H4C, from the hoist sling fittings. Position the hoist sling fittings over the engine mount roll fittings at waterline 199.625 and insert the pins,locking them in position.

Step 3. Raise the hoist sufficiently to take the slack out of the hoisting cables. Remove four AN7-11A bolts from each adapter kit flange, Part Number 7161-752002-29, and lift on the hoist to disengage the engine assembly from the workstand. If the engine shows a tendency to rotate in the hoist, the location of the Fitting Bracket, Part Number 7161-753001-13, should be adjusted.

Step 4. Remove twelve NAS674-4H bolts from the bottom side of the LLRV engine mount. These bolts are located as follows:

(a) Four centered about a point 14.387 inches forward of the engine and 14.205 inches to the right side.

(b) Four centered about a point 14.387 inches forward of the engine and 14.205 inches to the left side.

CAUTION

Do not remove the seven 3/16-inch diameter bolts found in the same general area.

(c) Four centered about a point on the LLRV longitudinal axis and 20.218 inches aft of the lateral engine centerline.

Step 5. Loosely attach three engine mount plates with centering pins pointing down to the locations described in Step 4 using twelve NAS674-16H bolts. The engine mount plates consist of two Part Number 503 and one Part Number 502. Part Number 502 has shorter hole spacings and should be located at the most aft mounting point (location (c) in Step 4 above).

Step 6. Remove large tang from master ring (at engine mount location) and position the master ring beneath the LLRV engine so that the areas stamped FWD and USE AGAINST VEHICLE are properly oriented with respect to the LLRV.

Step 7. Raise the master ring up and around the LLRV engine assembly until the aft tang on the inside diameter of the ring engages the unused aft main engine mount slot. Replace and engage the forward tang in the forward right engine mount slot. During this operation, the spherical ends of the centering pins in the loosely attached engine mount plates are inserted into appropriate positioning holes of the master ring.

Step 8. Attach master ring to LLRV engine using two captive pins, Part Number 7161-421028-1, inserted through the ring tangs and main engine mounts.

Step 9. Tighten the twelve NAS674-16H bolts in the engine mount plates.

Step 10. Remove the large tang from the master ring and remove the master ring from the engine assembly. Replace tang on master ring. Ensure that the support truss is properly oriented with the FWD notation on the triangular base corresponding to forward on the engine assembly.

Step 11. Using the overhead hoisting device, lift and then lower the engine onto the center of gravity fixture until the centering pins of the engine mount plates slip into the alignment holes of the mount fittings attached to the top ring of the support truss assembly.

CAUTION

Proceed with extreme care when lowering the engine to assure that clearances exist between components and the fixture and that no damage occurs as the alignment pins engage the mount fittings.

Step 12. Secure the engine to the center of gravity fixture by installing three 1/2-inch diameter socket head cap screws with the warning streamers up through the top of the mount fittings and into the engine mount plates.

Step 13. Remove the engine vertical hoist sling.

2.4.3 Weighing Procedure. -

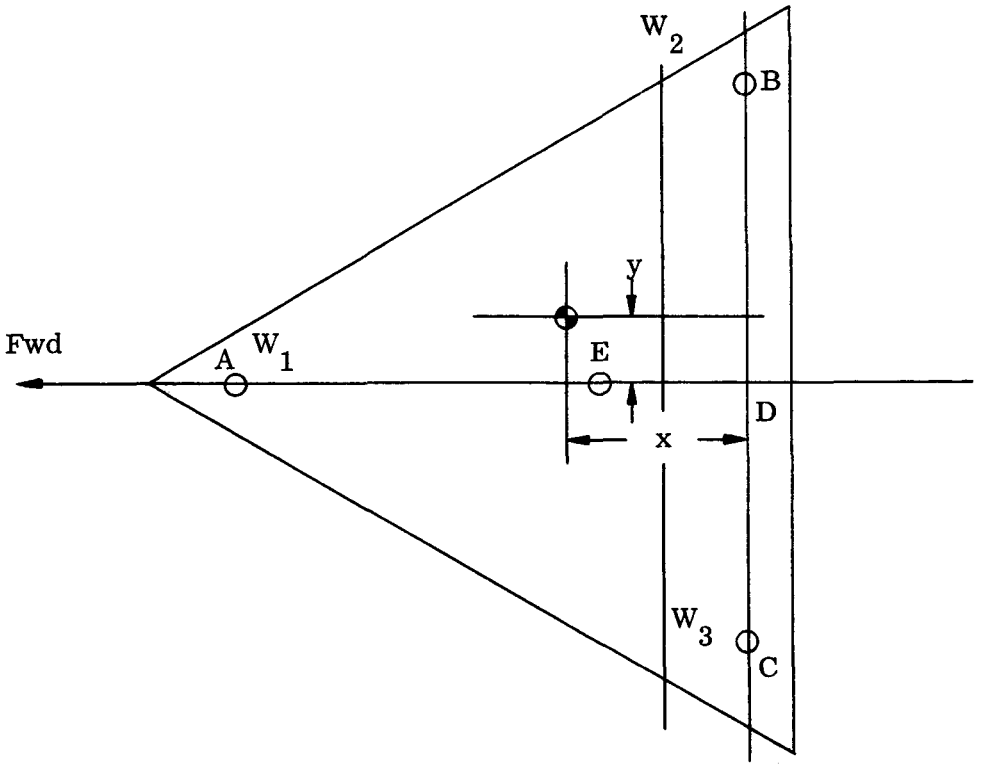
Step 1. Record the scale readings as shown on the sample Weighing Record Form II-3.

Step 2. Repeat the readings as necessary to ensure accuracy, upsetting the scale beams between subsequent readings. When the fixture is removed, check the scale zero errors and record all results as required. (See Form II-3.)

Step 3. Locate the combined center of gravity of the engine assembly and the fixture by taking moments:

$$x = \left(\frac{W_1 \times AD}{W_1 + W_2 + W_3} \right) \text{inches}$$

$$y = \left(\frac{W_2\ BD - W_3\ CD}{W_1 + W_2 + W_3} \right) \text{inches}$$



Dimensions AD, BD and DC are inscribed on the fixture

2.4.4. Procedure for Removing the Jet Engine Assembly from the Center of Gravity Fixture. -

Step 1. Using the overhead hoisting device, lower and position the engine vertical sling assembly and attach the sling fittings to the engine mount roll fittings using the pins provided.

CAUTION

Do not attempt to raise the engine at this time as severe damage to the engine mount may result. The hoist sling is attached at this time to eliminate possible tipping and subsequent damage to the engine during scale and fixture removal operations.

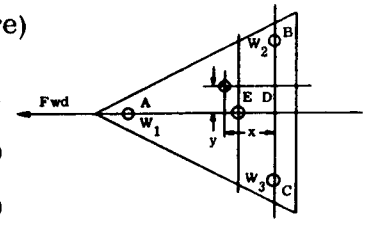
Step 2. Unlock the casters. Transfer the weight of the fixture and engine assembly

WEIGHING RECORD

GIMBALLED EQUIPMENT AND CENTER OF GRAVITY FIXTURE

DATE	PLACE	WEIGHED BY	
ENGINE NO.	SCALES USED		
JACKPOINT	SCALE READING	TARE	NET WEIGHT
A			W_1
B			W_2
C			W_3
Total as Weighed			

MEASUREMENTS (Inscribed on fixture)



AD = _____ inches, the distance from jackpoint A to BC

BD = _____ inches, the distance from jackpoint B to AD

DC = _____ inches, the distance from jackpoint C to AD

DE = _____ inches, the distance from BC to the projected engine vertical centerline

CENTER OF GRAVITY CALCULATIONS

x = distance of center of gravity from BC

y = distance of center of gravity from AD

$$x = \left(\frac{W_1 \times AD}{W_1 + W_2 + W_3} \right) \text{inches} = \_\_\_\_\_ \text{inches}$$

$$y = \left(\frac{(W_2 \times BD) - (W_3 \times CD)}{W_1 + W_2 + W_3} \right) \text{inches} = \_\_\_\_\_ \text{inches}$$

Locate the center of gravity with respect to AD by comparing W_2 and W_3.

WEIGHING RECORD

GIMBALLED EQUIPMENT AND CENTER OF GRAVITY FIXTURE

COMBINED WEIGHT AND CENTER OF GRAVITY OF FIXTURE AND BASIC GIMBALLED EQUIPMENT

Convert centers of gravity x and y to vehicle Body Stations (X), and Buttock Lines (Y).

BS $X = (200 + ED - x)$ inches = _____ inches

BL $Y = (200 \pm y)$ inches = _____ inches

Determine the correct sign for y by comparing the values of W_2 and W_3.

If $W_3 > W_2$, y is negative

If $W_2 > W_3$, y is positive

If $W_2 = W_3$, y is zero

COLUMN I					
ITEMS WEIGHED BUT NOT PART OF BASIC GIMBALLED EQUIPMENT	WEIGHT POUNDS W	ARM x INCHES	MOMENT Wx POUND-INCHES	ARM y INCHES	MOMENT Wy POUND-INCHES
Total Col. I					

WEIGHING RECORD

GIMBALLED EQUIPMENT AND CENTER OF GRAVITY FIXTURE

COLUMN II					
BASIC ITEMS NOT ON GIMBALLED EQUIPMENT WHEN WEIGHED	WEIGHT W POUNDS	ARM x INCHES	MOMENT Wx POUND-INCHES	ARM y INCHES	MOMENT Wy POUND-INCHES
Total Column II					

DESCRIPTION	WEIGHT W POUNDS	ARM x INCHES	MOMENT Wx POUND-INCHES	ARM y INCHES	MOMENT Wy POUND-INCHES
Total as Weighed (from Sheets 1 and 2)					
Gimbal Ring	+	200.0	+	200.0	+
Engine Oil					
Hydraulic Oil					
Total Col. I Items	-		-		-
Total Col. II Items	+		+		+
Fixture and Basic Gimballed Equipment Total					

WEIGHING RECORD

GIMBALLED EQUIPMENT AND CENTER OF GRAVITY FIXTURE

DETERMINATION OF LATERAL CENTERS OF GRAVITY OF GIMBALLED EQUIPMENT

DESCRIPTION	WEIGHT W POUNDS	ARM x INCHES	MOMENT Wx POUND-INCHES	ARM y INCHES	MOMENT Wy POUND-INCHES
Fixture and Basic Gimballed Equipment (Form II-3, Sheet 3)					
Fixture (Form II-1, Sheets 1 and 2)	-		-		-
Basic Gimballed Equipment					

Compare this weight of the basic gimballed equipment with that obtained in Form II-2, sheet 3. The two should agree.

Enter this weight on the Gimballed Equipment Basic Weight and Balance Record, Form II-4.

Form II-4

BASIC WEIGHT AND BALANCE RECORD

GIMBALLED EQUIPMENT

CONTINUOUS HISTORY OF CHANGES IN STRUCTURE OR EQUIPMENT AFFECTING WEIGHT AND BALANCE

ENGINE NO. _____

DATE	COMPLETE DESCRIPTION OF CHANGE	WEIGHT AND MOMENT CHANGES AND RUNNING TOTAL BASIC WEIGHT						
		WEIGHT W POUNDS	ARM x INCHES	MOMENT Wx POUND-INCHES	ARM y INCHES	MOMENT Wy POUND-INCHES	ARM z INCHES	MOMENT Wz POUND-INCHES

from the scales to the casters by turning the adjusting screws. Remove the scales or the 10-1/4-inch spacers if a flush weighing facility is used.

Step 3. Remove three 1/2-inch diameter socket head cap screws and warning streamers. These screws attach the LLRV engine mount plates to the mount fittings of the CG fixture.

CAUTION

Do not under any circumstances attempt to hoist the engine without first removing the three 1/2-inch diameter screws. Serious damage to the engine mount could occur if the engine is hoisted while still attached to the fixture.

Step 4. Using the overhead hoisting device, carefully raise the engine out of the CG fixture to a point where the engine exhaust cone will clear the top fittings of the truss.

CAUTION

Proceed with extreme care when raising the engine out of the fixture to assure that clearances exist between engine components and the fixture.

Step 5. Lower the engine into the workstand and insert the eight AN7-11A bolts through the flanges and into the mount roll fittings. Tighten these bolts and check that the NAS1356-S2S09F pins of the adapter kit pivot are installed. Remove the pins from the hoist fittings and remove the hoisting sling. Drain engine hydraulic and lubricating oil systems if the engine is to be turned to the horizontal position.

2.4.5. Maintenance of Basic Weight and Balance Records. - The Basic Weight and Balance Record (Form II-4) is a continuous history of the basic weight and centers of gravity resulting from structural and equipment changes. At all times, the last entry on this form is considered the current basic weight and center of gravity status of the basic gimballed equipment. The form must be completed each time the gimballed equipment is weighed and

is used to record all changes which affect its basic weight and balance. This form should be checked before the vehicle is balanced for a particular flight (see Section III) and loading personnel should refer to this form before preparing any load.

When the gimballed equipment is reweighed, the weights and moments entered in the form must reflect the basic weight as derived on Weighing Record Form II-2, sheet 3, and Weighing Record Form II-3, sheet 4. If an item is to be added to or subtracted from the gimballed equipment listed in the LLRV Equipment Checklist, Table 1-8, enter the item number, description, applicable weight, and moments on the Gimballed Equipment Basic Weight and Balance Record Form II-4. If the item is permanently added or removed, make the necessary changes to the LLRV equipment checklist. Any change or modification which is caused by a specific order should carry a reference to the order number and date which authorizes the change.

2.5. BASIC WEIGHT AND CENTER OF GRAVITY DETERMINATION OF THE COMPLETE VEHICLE.

2.5.1. General. - The object of this procedure is to obtain an accurate weight and center of gravity of the vehicle in the basic weight condition. This will serve as the starting point for obtaining a properly balanced vehicle at an operating weight empty condition.

CAUTION

It is extremely important that this procedure be accurately performed. A vehicle which is flown with the centers of gravity outside the established limits may result in unmanageable control problems and possible disaster. Every precaution must be taken to ensure that the basic weight and centers of gravity are correct.

2.5.2. Preparation for Weighing. -

Step 1. Determine the weight and lateral centers of gravity of the center of gravity fixture as described in Paragraph 2.2.

Step 2. Determine the weight and vertical center of gravity of the gimballed equipment as described in Paragraph 2.3.

Step 3. Determine the lateral centers of gravity of the gimballed equipment as described in Paragraph 2.4.

Step 4. Obtain three scales of at least 2000 pounds capacity and accurate to within ±0.50 pound (either platform or flush type). Ensure that the scales are correctly calibrated and levelled.

Step 5. Position and level the weighing fixture as described in Paragraph 2.2.2. Note scale readings and compare with figures obtained when fixture was last weighed. If a discrepancy exists, determine and rectify the cause before proceeding.

2.5.3. Procedure for Positioning the LLRV on the Center of Gravity Fixture. -

Step 1. Remove twelve NAS674-4H bolts from the bottom side of the LLRV engine mount. These bolts are located as follows:

(a) Four centered about a point 14.387 inches forward of the engine and 14.205 inches to the right side.

(b) Four centered about a point 14.387 inches forward of the engine and 14.205 inches to the left side.

CAUTION

Do not remove the seven 3/16 inch diameter bolts found in the same general area.

(c) Four centered about a point on the LLRV longitudinal axis and 20.218 inches aft of the lateral engine centerline.

Step 2. Loosely attach three engine mount plates with centering pins pointing down to the locations described in Step 1 using twelve NAS674-16H bolts. The engine mount plates consist of two part number 503 and one part number 502. Part number 502 has shorter hole spacings and is located at the most aft mounting point (location (c) in Step 1).

Step 3. Remove the large tang from master ring (at engine mount position) and position the master ring beneath the LLRV engine so that the areas stamped FWD and USE AGAINST VEHICLE are properly oriented with respect to the LLRV.

Step 4. Raise the master ring up and around the LLRV engine assembly until the aft tang on the inside diameter of the ring engages the unused aft main engine mount slot. Replace and engage the forward tang in the unused forward right engine mount slot. During this operation, the spherical ends of the centering pins in the loosely attached engine mount plates are inserted into appropriate positioning holes of the master ring.

Step 5. Attach master ring to LLRV engine using two captive pins, part number 7161-421028-1, inserted through the ring tangs and main engine mounts.

Step 6. Tighten the twelve NAS674 -16H bolts in the engine mount plates.

Step 7. Remove the large tang from the master ring and remove the master ring from engine assembly. Replace tang on master ring.

Step 8. Install the gimbal ground locks. (See Figure 2-5.)

Step 9. Remove the four AN5-10 bolts which attach the drogue parachute cables to the four top corners of the LLRV center body structure.

Step 10. Attach the link of the LLRV Hoist Sling, part number 7161-753002, to an overhead hoisting device of two ton minimum capacity.

Step 11. Using the hoisting device, lower the LLRV hoist sling so that the drop cables can be attached with AN5 bolts to the drogue parachute terminals located at each of the four top corners of the LLRV center body structure. These terminals are made available by removal of the bolts in Step 9.

Step 12. Position the support truss assembly in the area accessible to the overhead hoisting device with the FWD notation on the triangular base oriented properly with respect to forward on the LLRV.

Step 13. Using the overhead hoisting device, lift and position the complete LLRV to permit clearance between the engine exhaust cone and the top of the support truss assembly. Lower the complete LLRV on to the CG fixture until the centering pins of the engine mount plates slip into the alignment holes of the mount fittings attached to the top ring of the support truss assembly.

To be supplied

Figure 2-5. Gimbal Ground Locks

CAUTION

Proceed with extreme care when lowering the LLRV to assure that sufficient clearances exist between components and fixture and that no damage occurs as the alignment pins engage the mount fittings.

Step 14. Secure the LLRV to the CG fixture by installing three 1/2-inch diameter socket head cap screws, with warning streamers, up through the top of the mount fittings and into the engine mount plates.

Step 15. Slack off, but do not remove the LLRV hoist sling. This is a precautionary measure to prevent possible damage to the LLRV by tipping during the leveling operation. A view of the vehicle mounted on the center of gravity fixture is shown in Figure 2-6.

2.5.4. Determination of Basic Weight and Lateral Centers of Gravity of the Vehicle Less Gimballed Equipment. -

Step 1. Check the vehicle and gimballed equipment against the equipment checklist (Table 1-8). Note all discrepancies. Make certain fuel and hydrogen peroxide tanks are drained before weighing.

Step 2. Seat and properly strap in the designated pilot in the cockpit, with his feet and hands resting lightly on the appropriate controls. The pilot must wear his normal flight suit and equipment. If the designated pilot is not available for weighing, a substitute pilot who most closely approximates the actual pilot's weight should be used. A pilot must always be aboard during weighing to eliminate any tendency of the vehicle to topple and to avoid the necessity of making large center of gravity corrections for the final balancing. Record the weight of the pilot or his substitute.

To be supplied by NASA

Figure 2-6. Vehicle on Center of Gravity Fixture

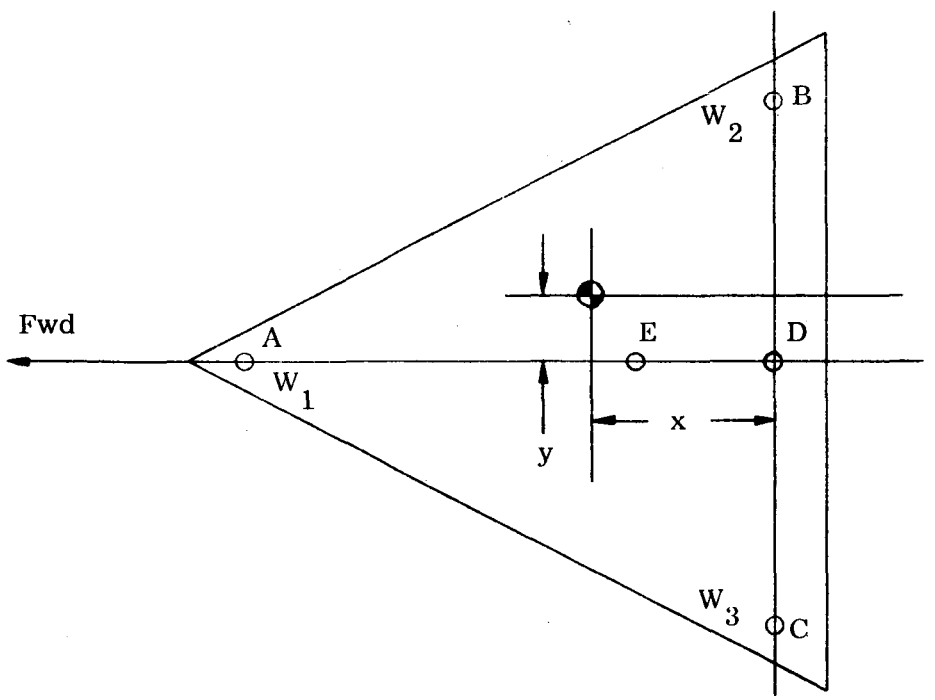
Step 3. Level the vehicle utilizing the leveling lugs provided and a Clinometer, Hilger and Watts Model 75022 or equivalent, adjusting the pitch and roll gimbal locks. The vehicle must be levelled as accurately as possible and within ±10 minutes, maximum.

Step 4. Remove the hoist sling and replace the four AN5 bolts in the drogue parachute attachment fittings.

Step 5. Record the scale indications on Weighing Record Form II-5, Sheet 1. Repeat the readings as necessary to ensure accurate results. Upset the beam on each scale between subsequent readings. Locate the combined center of gravity of the vehicle and fixture by taking moments:

$$x = \left(\frac{W_1 \times AD}{W_1 + W_2 + W_3} \right) \quad \text{inches}$$

$$y = \left(\frac{(W_2 \times BD) - (W_3 \times CD)}{W_1 + W_2 + W_3} \right) \text{inches}$$



Dimensions AD, BD, CD and DE are inscribed on the fixture.

Step 6. Determine the lateral centers of gravity of the basic vehicle. The weight and center of gravity of the fixture and basic gimballed equipment was obtained in Paragraph 2.4. Adjust these figures as necessary and obtain the basic weight and lateral centers of gravity of the vehicle by subtraction. It is obviously an advantage if the configuration of the gimballed equipment is the same for both weighings. In particular, the fluid systems should reflect the basic configuration. Sheets 1 through 5 of the Weighing Record Form II-5 when completed, will give the actual lateral centers of gravity of the vehicle.

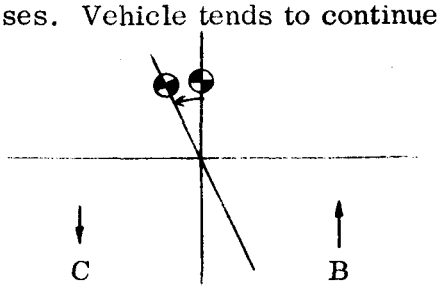
2.5.5 Determination of the Vertical Center of Gravity of the Basic Vehicle. - If the value of D_1, as obtained on Sheet 5 of Weighing Record Form II-5, is less than 0.1, the vertical center of gravity may be found as described in Paragraph 2.5.5.1. However, if the value of D_1 is greater than 0.1, proceed as directed in Paragraph 2.5.5.2.

2.5.5.1. Value of D_1 Less Than 0.1. -

Step 1. Remove the AN5 bolts from the drogue parachute cable attachment fittings and attach the hoist sling. Remove the gimbal lock on the roll actuator and carefully lower the hoist sling to develop some slack in the sling cables. Since the value of D_1 is less than 0.1, the center of gravity is directly above or below the vehicle roll axis and the vehicle should have no tendency to roll. Using caution, roll the vehicle a few degrees right or left by manually grasping the two fore and aft legs. Note changes in scale readings at jack points B and C and use the following diagrams to determine whether the vertical center of gravity is above or below waterline 200.0.

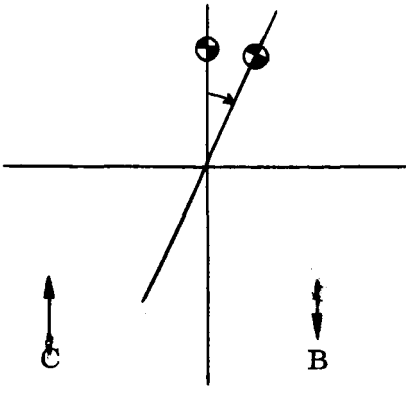
Case 1. Vertical Center of Gravity Above WL200. -

(a) Roll vehicle to left. - Scale reading at C increases while B decreases. Vehicle tends to continue rolling to left.



View Looking Forward Along Roll Axis

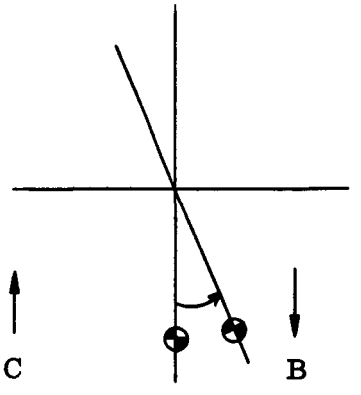
(b) Roll vehicle to right. - Scale reading at B increases while C decreases. Vehicle tends to continue rolling to right.



View Looking Forward Along Roll Axis

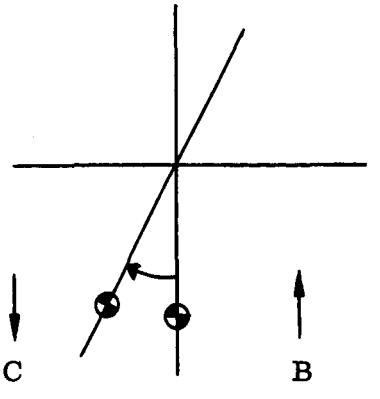
Case 2. Vertical Center of Gravity Below WL200. -

(a) Roll vehicle to left. - Scale reading at C decreases while B increases. Vehicle tends to return to level position.



View Looking Forward Along Roll Axis

(b) Roll vehicle to right. - Scale reading at B decreases while C increases. Vehicle tends to return to level position.



View Looking Forward Along Roll Axis

Step 2. Having now determined whether the vertical center of gravity is above or below waterline 200, attach the special gimbal lock and lock the vehicle at a roll angle of between 25 and 30 degrees left or right.

CAUTION

Ensure that the hoist sling is securely attached during this operation. When the vehicle is locked in the rolled position, remove the hoist sling and replace the AN5 bolts.

Step 3. Note the scale indication at jackpoint A. If this reading has changed more than plus or minus one pound from the reading taken when the vehicle was level, check the vehicle pitch angle using the clinometer. Adjust the pitch gimbal lock as necessary to duplicate the pitch angle reading when the vehicle was level.

Step 4. Record the scale indications on Sheet 5 of Weighing Record Form II-5. Measure the angle of roll using a clinometer and the level lugs provided. Repeat the scale readings as necessary to ensure accuracy, upsetting the scale beams between subsequent readings. The vertical center of gravity can now be located by performing the computations on Weighing Record Form II-5, Sheet 6. Completion of Sheets 7 and 8 will give the vertical center of gravity of the basic vehicle. When the vertical center of gravity has been determined, proceed as directed in Paragraph 2.5.6 and subsequent.

2.5.5.2. Value of D_1 Greater Than 0.1. -

Step 1. Remove the AN5 bolts from the drogue parachute attachment fittings and attach the hoist sling. Remove the gimbal lock on the roll actuator and carefully lower the hoist sling to develop some slack in the sling cables. Since the valve of D_1 is greater than 0.1, the center of gravity is to one side of the vehicle roll axis. Thus the vehicle will have a tendency to roll. If the center of gravity is to the right side of the roll axis, the vehicle will roll to the right, and vice versa.

Using extreme caution, allow the vehicle to roll about five degrees without restraint, but with the hoist sling still attached. Ensure that the vehicle starts to roll from the level position and repeat the process until results are consistent.

Step 2. If the unrestrained vehicle rolled to the right, the gimbal lock must now be attached such that the vehicle is rolled to the left and vice versa, the object being to always raise the center of gravity when rolling the vehicle. Insert the special gimbal lock to roll the vehicle about 25 or 30 degrees.

CAUTION

Ensure that the hoist sling is securely attached during this operation. When the vehicle is locked in the rolled position, remove the hoist sling and replace the AN5 bolts.

Step 3. Note the scale indication at jackpoint A. If this reading has changed by more than plus or minus one pound from the reading taken when the vehicle was level, check the vehicle pitch angle using the clinometer. Adjust the pitch gimbal lock as necessary to duplicate the pitch angle reading when the vehicle was level.

Step 4. Record the scale indications as shown on Weighing Record Form II-5, Sheet 5. Measure the angle of roll using the clinometer and the level lugs provided. Repeat the scale readings as necessary to ensure accuracy, upsetting the scale beams between subsequent readings. The vertical center of gravity can now be located by performing the computations on Weighing Record Form II-5, Sheet 6. Completion of Sheets 7 and 8 of Form II-5 will give the vertical center of gravity of the basic vehicle.

2.5.6. Procedure for Removing the LLRV from the Center of Gravity Fixture. -

Step 1. Remove the four AN5 bolts from the drogue parachute cable attachment fittings and attach the hoist sling. Remove the special gimbal lock and carefully return the LLRV to the level position. Insert the level roll gimbal lock and remove the pilot from the cockpit.

CAUTION

Do not attempt to raise the overhead hoisting device at this time as severe damage to the LLRV could result. The hoist sling is attached at this time to eliminate possible tipping and subsequent damage to the LLRV during scale and fixture removal operations.

Step 2. Unlock the casters and transfer the weight of the fixture and the LLRV from the scales to the casters by turning the adjusting screws. Remove the scales or the 10-1/4-inch spacers if a flush weighing facility is used.

Step 3. Remove three 1/2-inch diameter socket head cap screws and warning streamers. These screws attach the LLRV engine mount plates to the mount fittings of the CG fixture.

CAUTION

Do not under any circumstances attempt to hoist the LLRV without first removing the three 1/2-inch diameter screws. Serious damage to the engine mount could occur if the LLRV is hoisted while still attached to the fixture.

Step 4. Carefully raise the LLRV out of the CG fixture to a point where the engine exhaust cone will clear the top fittings of the truss, using the overhead hoisting device.

CAUTION

Proceed with extreme care when raising the LLRV out of the fixture to assure that sufficient clearance exists between the vehicle components and the fixture.

Step 5. Remove the support truss assembly from beneath the LLRV. Check and record the scale zero errors.

Step 6. Carefully lower the LLRV to the floor using the overhead hoisting device.

Step 7. Remove the four AN5 bolts which attach the LLRV hoist sling to the drogue parachute terminals.

Step 8. Remove the overhead hoisting device and the LLRV hoist sling. Secure the LLRV drogue parachute terminals to the ball end terminals at the corners of the center body structure with AN5-10 bolts.

Step 9. Remove three engine mount plates from under side of LLRV engine mount. These plates are attached with twelve NAS674-16H bolts. Install twelve NAS674-4H bolts in the holes.

2.5.7. Maintenance of Basic Weight and Balance Records. - The Basic Weight and Balance Record, Form II-6, is a continuous history of the basic weight and centers of gravity resulting from structural and equipment changes. At all times, the last entry on this form is considered the current basic weight and center of gravity status of the basic vehicle.

Form II-6 must be completed each time the vehicle is weighed and should be used to record all changes which affect the vehicle's basic weight and balance. The following are typical of such changes:

(a) Any alterations made to the equipment or structure, whether temporary or permanent.

(b) The addition or subtraction of ballast.

(c) Movement of the aft equipment platform.

(d) Reweighing the vehicle.

Form II-6 should be checked before the vehicle is balanced for a particular flight. Loading personnel should refer to this form before preparing any load.

When the vehicle is reweighed, the weight and moments entered in the form must reflect the basic weight as derived on Sheets 5 and 8 of the Weighing Record Form II-5. The configuration of the aft equipment platform must be the same as noted on Sheet 1 of Form II-5.

If an item which is to be added to or removed from the vehicle is listed in the equipment checklist (Table 1-8), enter the item number, description, applicable weight, and moments on the basic weight and balance record. If the item is permanently added or removed,make the necessary changes to the equipment checklist. Any change or modification caused by a specific order should carry a reference to the order number and date which authorizes the change.

2.6. AFT EQUIPMENT PLATFORM.

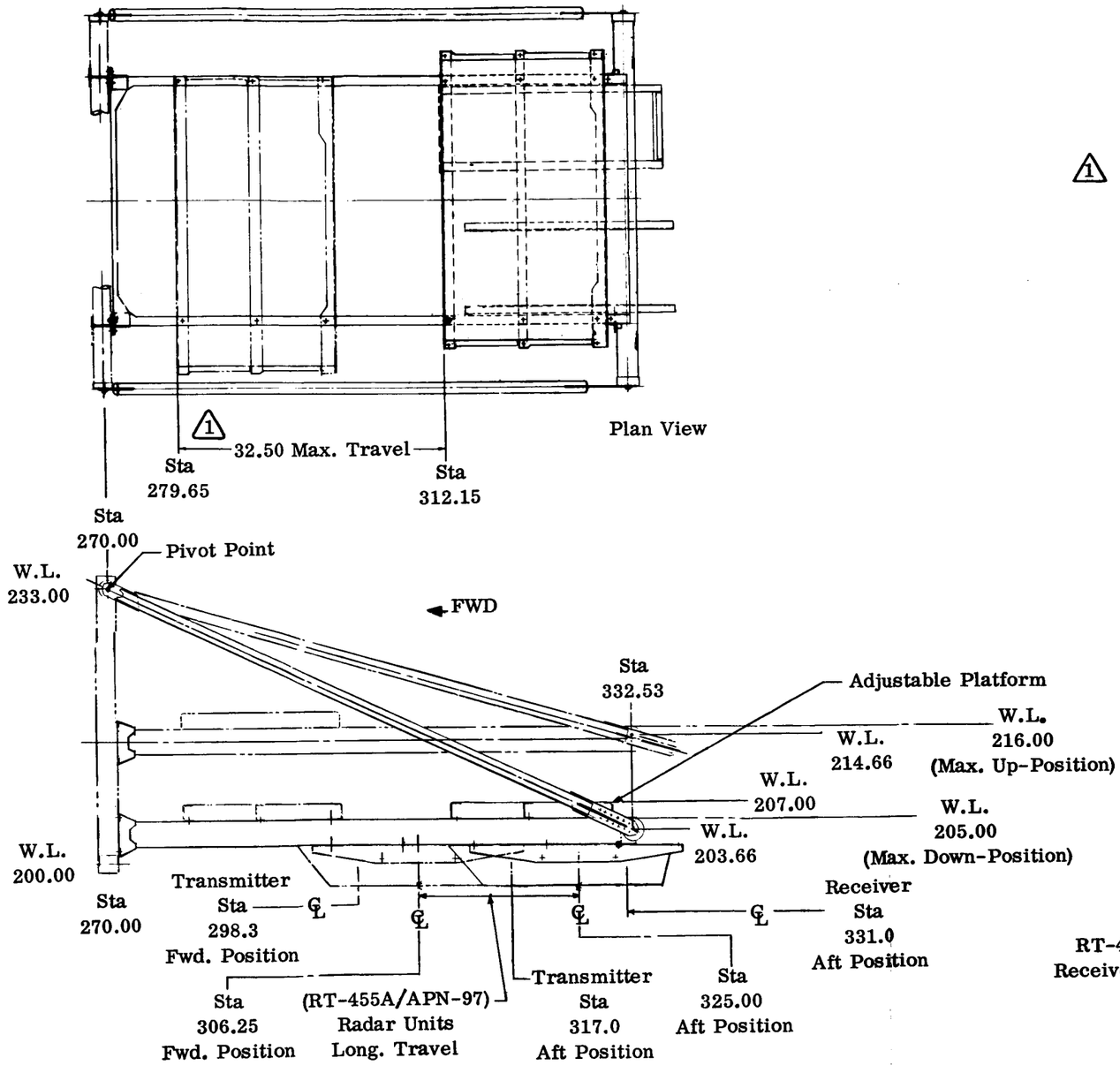
2.6.1. General. - The aft equipment platform is illustrated in Figure 2-7. Its function is to provide those moment changes necessary to maintain a required vehicle center of gravity location in three axes simultaneously. Provisions are therefore made to allow the movement of weights in three mutually perpendicular directions to produce the required moments. The movable items on the aft equipment platform can be broken down into three major units as indicated in Paragraphs 2.6.1.1 through 2.6.1.3.

2.6.1.1. Items Movable Vertically Up and Down. - All items of equipment and structure aft of the vertical beams at Station 270 can be moved a total of ±5.5 inches up or down from the neutral position in increments of one inch.

2.6.1.2. Items Movable Horizontally Forward and Aft. - There are two groups of equipment which fall under this heading.

(a) All equipment on the adjustable platform which can be moved forward and aft for a total distance of ±16.25 inches in increments of 1.25 inches.

(b) The doppler receiver-transmitter assembly mounted underneath the platform which can be moved a total distance of ±9.375 inches from the neutral position in increments of 1.25 inches.



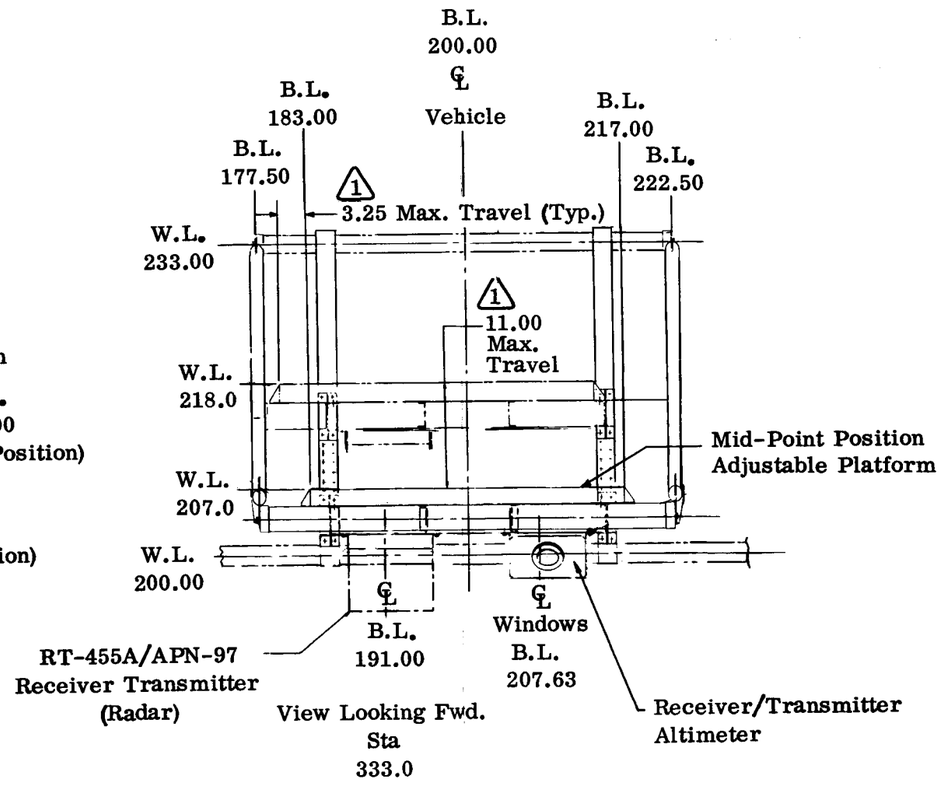


Figure 2-7. Aft Equipment Platform

2.6.1.3. Items Movable Laterally. - Lateral movement is confined to those items mounted on the adjustable platform. A total movement of ±3.25 inches is possible, in increments of 0.812 inch.

2.6.2. Determination of Change in Moment as Equipment is Moved. - In order to be able to adjust the vehicle center of gravity with the minimum of inconvenience, it is necessary to know the exact moment change accompanying the movement of the three major units of equipment. An approximate figure can be obtained by weighing the various movable units previously described. Knowing the vehicle weight and center of gravity and the increments through which the movable weight can be moved, it is a straight forward matter to calculate the total movement required to effect the required adjustment.

However, due to the indeterminate effects of cable assemblies, the actual moment change will be somewhat different. Measurement of the actual change should be carried out with the vehicle mounted on the center of gravity fixture as described in Paragraph 2.5. The movable units should be adjusted in steps and careful calculations made of the center of gravity changes produced. Thus a table can be constructed to show the precise actual c.g. with the movable units at various locations.

2.6.3. Maintenance of Basic Weight Records. - The Basic Weight Record, Form II-7, is a continuous history of the basic weight of the movable units resulting from structural and equipment changes. At all times, the last entry on these forms is considered the current basic weight status. Form II-7 must be completed each time the movable equipment is weighed and all changes which affect the weight must be recorded. This form should be checked before the vehicle is balanced for any particular flight or operation.

If an item which is to be added to or subtracted from the movable equipment is listed in the equipment checklist (Table 1-8), enter the item number, description, and applicable weight on the basic weight record. If the item is permanently added or removed, make the necessary changes to the equipment checklist.

Any change or modification caused by a specific order should carry a reference to the order number and date which authorizes the change.

All structural and equipment changes which affect the weight of movable units must also be shown on the vehicle basic weight and balance record. Those changes which do not

affect the weight but which do affect the location of the movable units will appear only on the vehicle record. Refer to Paragraph 2.5.7.

2.7. POWER PLANT CENTER OF GRAVITY AND THRUSTLINE OFFSETS.

2.7.1. General. - Due to the effect of the engine gearbox, generator, fuel control unit, and other unsymmetrically located items, the power plant center of gravity will not coincide with the engine thrustline. This produces moments in flight which must be compensated.

2.7.2. Method of Compensation. - The moments created by the engine center of gravity and thrustline offset are compensated by adjusting the vehicle center of gravity to produce an equal and opposite moment about the intersection of the pitch and roll axes.

This is accomplished in practice by adjusting the aft equipment platform to produce a vehicle center of gravity at operating weight empty, which coincides with the intersection of the vehicle pitch and roll axes. The procedure for achieving this result is fully explained in Paragraph 3.2.

WEIGHING RECORD

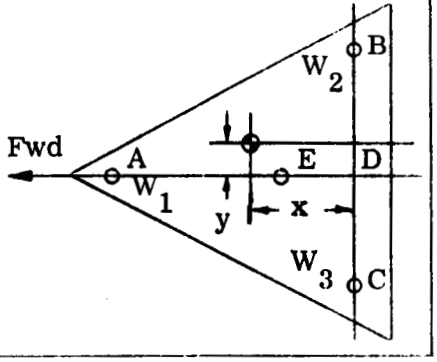
1. VEHICLE, GIMBALLED EQUIPMENT, AND FIXTURE

DATE	PLACE		WEIGHED BY
ENGINE NO.	VEHICLE NO.	PILOTS WEIGHT	POUNDS
VEHICLE ATTITUDE (LEVEL)	PITCH °	ROLL °	
FUEL SYSTEM: DRY ☐	LINES ONLY FULL ☐	_____ LB	TANKS EMPTY ☐
ROCKET SYSTEM: DRY ☐	LINES ONLY FULL ☐	_____ LB	TANKS EMPTY ☐
SCALES USED			

LOCATION OF MOVABLE EQUIPMENT:

(a) Items with Vertical Travel:
(b) Items with Lateral Travel:
(c) Doppler Rec/Trans - Horizontal:
(d) Equipment Platform - Horizontal:

JACKPOINT	SCALE READING	TARE	NET WEIGHT
A			W_1
B			W_2
C			W_3
Total as Weighed			



MEASUREMENTS (Inscribed on Fixture)

AD = _____ inches, the distance from jackpoint A to BC
BD = _____ inches, the distance from jackpoint B to AD
DC = _____ inches, the distance from jackpoint C to AD
DE = _____ inches, the distance from BC to the projected engine vertical centerline

CENTER OF GRAVITY CALCULATIONS

x = distance of center of gravity from BC
y = distance of center of gravity from AD

$$x = \left(\frac{W_1 \times AD}{W_1 + W_2 + W_3} \right) \text{ inches} = \_\_\_\_\_ \text{ inches}$$

$$y = \left(\frac{(W_2 \times BD) - (W_3 \times CD)}{W_1 + W_2 + W_3} \right) \text{ inches} = \_\_\_\_\_ \text{ inches}$$

Locate the center of gravity with respect to AD by comparing W_2 and W_3.

WEIGHING RECORD

1. VEHICLE, GIMBALLED EQUIPMENT, AND FIXTURE

Convert centers of gravity x and y to vehicle Body Stations (X), and Buttock Lines (Y).

BS $X = (200 + ED - x)$ inches = _____ inches

BL $Y = (200 \pm y)$ inches = _____ inches

Determine the correct sign for y by comparing the values of W_2 and W_3.

If $W_3 > W_2$, y is negative

If $W_2 > W_3$, y is positive

If $W_2 = W_3$, y is zero

2. WEIGHT AND CENTER OF GRAVITY OF GIMBALLED EQUIPMENT AND FIXTURE

COLUMN I					
BASIC ITEMS NOT ON GIMBALLED EQUIPMENT WHEN WEIGHED	WEIGHT W POUNDS	ARM x INCHES	MOMENT Wx POUND - INCHES	ARM y INCHES	MOMENT Wy POUND - INCHES
Total Column I Items					

WEIGHING RECORD

2. WEIGHT AND CENTER OF GRAVITY OF GIMBALLED EQUIPMENT AND FIXTURE (CONT)

COLUMN II					
ITEMS WEIGHED BUT NOT PART OF BASIC GIMBALLED EQUIPMENT	WEIGHT POUNDS W	ARM x INCHES	MOMENT Wx POUND-INCHES	ARM y INCHES	MOMENT Wy POUND-INCHES
Total Column II Items					

DESCRIPTION	WEIGHT W POUNDS	ARM x INCHES	MOMENT Wx POUND-INCHES	ARM y INCHES	MOMENT Wy POUND-INCHES
Fixture and Basic Gimballed Equipment (Form II-3, Sheet 3)					
Less Total Column I Items	-		-		-
Plus Total Column II Items	+		+		+
Fixture and Gimballed Equipment as Weighed					

WEIGHING RECORD

3. BASIC WEIGHT AND LATERAL CENTERS OF GRAVITY OF VEHICLE

COLUMN I					
ITEMS WEIGHED BUT NOT PART OF BASIC VEHICLE	WEIGHT W POUNDS	ARM x INCHES	MOMENT Wx POUND-INCHES	ARM y INCHES	MOMENT Wy POUND-INCHES
Pitch Gimbal Lock					
Roll Gimbal Lock					
Pilot					
Total Column I Items					

COLUMN II					
BASIC ITEMS NOT ON VEHICLE WHEN WEIGHED	WEIGHT W POUNDS	ARM x INCHES	MOMENT Wx POUND-INCHES	ARM y INCHES	MOMENT Wy POUND-INCHES
JP4 In Lines					
H_2O_2 In Lines					
Total Column II Items					

WEIGHING RECORD

3. BASIC WEIGHT AND LATERAL CENTERS OF GRAVITY OF VEHICLE (CONT)

DESCRIPTION	WEIGHT W POUNDS	ARM x INCHES	MOMENT Wx POUND-INCHES	ARM y INCHES	MOMENT Wy POUND-INCHES
Total as Weighed (Sheets 1 and 2)					
Fixture and Gimballed Equipment as Weighed (Sheet 3)	-		-		-
Less Total Column I Items (Sheet 4)	-		-		-
Plus Total Column II Items (Sheet 4)	+		+		+
Total Vehicle Only Basic Weight					

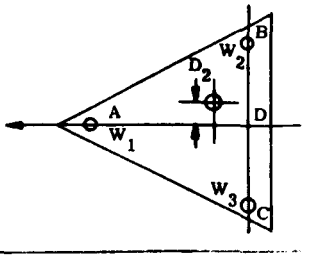
$D_1 = (\mp 200 \pm y) = (\mp 200 \pm \quad) = + \_\_\_\_\_$ inches

Note: The absolute value of D_1 is required. D_1 must always be positive, regardless of the value of y.

4. VERTICAL CENTER OF GRAVITY OF VEHICLE

ROLL ANGLE: RIGHT / LEFT cot θ _____ cosec θ _____

JACKPOINT	SCALE READING	TARE	NET WEIGHT
A			W_1
B			W_2
C			W_3
Total as Weighed			



MEASUREMENTS (Inscribed on Fixture)

BD = _____ inches, the distance from jackpoint B to AD.
CD = _____ inches, the distance from jackpoint C to AD.

WEIGHING RECORD

4. VERTICAL CENTER OF GRAVITY OF VEHICLE (CONT)

VERTICAL CENTER OF GRAVITY CALCULATIONS

D_2 = distance of center of gravity from AD at roll angle of θ degrees:

$$D_2 = \left[\frac{(W_2 \times BD) - (W_3 \times CD)}{W_1 + W_2 + W_3} \right] \text{ inches} = \_\_\_\_\_ \text{ inches.}$$

a. Value of $D_1 < 0.1$.

If the value of D_1 was less than 0.1 and the vertical center of gravity was above WL200. --

Vertical CG = WL200 + D_2 cosec θ

= WL200 +

= WL

If the value of D_1 was less than 0.1 and the vertical center of gravity was below WL200. -

Vertical CG = WL200 - D_2 cosec θ

= WL200 -

= WL

b. Value of $D_1 > 0.1$.

Vertical center of gravity

= WL200 + (D_1 cot θ - D_2 cosec θ)

= WL200 + ( )

= WL

Form II-5

WEIGHING RECORD

4. VERTICAL CENTER OF GRAVITY OF VEHICLE (CONT)

COLUMN I			
ITEMS WEIGHED BUT NOT PART OF BASIC VEHICLE	WEIGHT W POUNDS	ARM z INCHES	MOMENT Wz POUND-INCHES
Pitch Gimbal Lock			
Special Roll Gimbal Lock			
Pilot			
Total Column I Items			

COLUMN II			
BASIC ITEMS NOT ON VEHICLE WHEN WEIGHED	WEIGHT W POUNDS	ARM z INCHES	MOMENT Wz POUND-INCHES
JP4 in Lines			
H_2O_2 in Lines			
Total Column II Items			

DESCRIPTION	WEIGHT POUNDS	ARM z INCHES
Total as Weighed (Sheet 5)		
Fixture and Gimballed Equipment as Weighed (Sheet 3)	-	
Vehicle Only as Weighed		From Sheet 6

WEIGHING RECORD

4. VERTICAL CENTER OF GRAVITY OF VEHICLE (CONT)

DESCRIPTION	WEIGHT W POUNDS	ARM z INCHES	MOMENT Wz POUND-INCHES
Vehicle Only as Weighed (Sheet 7)			
Less Total Column I Items (Sheet 7)	-		-
Plus Total Column II Items (Sheet 7)	+		+
Total Vehicle Only Basic Weight			

The vehicle Basic Weight obtained here must agree with the basic weight obtained on Sheet 5.

Form II-6

BASIC WEIGHT AND BALANCE RECORD

CONTINUOUS HISTORY OF CHANGES IN STRUCTURE OR EQUIPMENT AFFECTING WEIGHT AND BALANCE

Vehicle No. _____

DATE	COMPLETE DESCRIPTION OF CHANGE	WEIGHT AND MOMENT CHANGES, RUNNING TOTAL, BASIC VEHICLE						
		WEIGHT W POUNDS	ARM x INCHES	MOMENT Wx POUND-INCHES	ARM y INCHES	MOMENT Wy POUND-INCHES	ARM z INCHES	MOMENT Wz POUND-INCHES

Form II-7

BASIC WEIGHT RECORD - MOVABLE EQUIPMENT

CONTINUOUS HISTORY OF CHANGES IN STRUCTURE OR EQUIPMENT AFFECTING WEIGHT

UNIT _____

VEHICLE NO. _____ UNIT DESCRIPTION: _____ SHEET _____

DATE	ITEM NO.		DESCRIPTION OF ARTICLE OR MODIFICATION	WEIGHT CHANGE		RUNNING TOTAL UNIT _____ WEIGHT POUNDS
	IN	OUT		ADDED (+) WEIGHT POUNDS	REMOVED (-) WEIGHT POUNDS	

SECTION III

FLIGHT LOADING AND BALANCING DATA

3.1. BALANCING AND LOADING PROCEDURES.

Balancing and loading of this vehicle are part of one and the same operation. Each particular flight must be balanced to account for variations in research equipment weights and/or individual pilot weights. Since these changes affect both operating weight empty and gross takeoff weight, vehicle balancing and loading become inseparable.

The following changes to operating weight empty are typical of those which will require that the vehicle be rebalanced:

(a) Substitution of pilots.
(b) Addition or removal of equipment.
(c) Change in helium gas pressure.
(d) Addition or removal of jet engine intake screens.

A satisfactory balance will be maintained indefinitely, provided the vehicle configuration and operating weight empty remain constant.

3.2. BALANCING AND LOADING FOR FLIGHT.

3.2.1. Preliminary Requirements. - The vehicle and gimballed equipment must be accurately weighed as described in Section II of this handbook. All basic weight record forms must be complete and up-to-date. A careful check should be made to ensure that no changes have been made to the vehicle or its equipment since the last entry in the Basic Weight and Balance Record Form II-6.

3.2.2. Weight and Balance Clearance Form. - The Weight and Balance Clearance Form III-1, records the weight and balance status of the vehicle for each flight. It serves as a worksheet on which the weight and balance computer records his calculations and all pertinent data relating to the loading.

An original and carbon copy of this form must be prepared for each loading. The original, carrying the signatures of responsibility, must be retained with the flight records to serve as the certificate of proper weight and balance clearance. The carbon copy should be filed for future reference.

Form III-1
1

WEIGHT AND BALANCE CLEARANCE – LLRV

FLIGHT DATE

FLIGHT NO.

FACILITY _____ | VEHICLE NO. _____ | ENGINE NO. _____ | PILOT _____ | PILOT WEIGHT _____ LB | RUNWAY ALTITUDE ___FT | AMBIENT TEMP. _____ °F

2 LIMITATIONS

Max. Allowable Gross T.O.W.		lb
Center of Gravity Limits (Compare with Actual Values)	X	199.75 to 200.25
	Y	199.75 to 200.25
	Z	199.50 to 200.00
Minimum Landing Fuel (Compare with Estimated Landing Fuels Below)	JP4	lb
	H_2O_2	lb

23 Estimated Landing Fuels

JP4 in Tanks (16)	lb	H_2O_2 in Tanks (19)	lb
Est. Usage	- lb	Est Usage	- lb
JP4 at Landing Est	lb	H_2O_2 at Landing Est	lb

H_2O_2 and JP4 System Conditions

15 JP4 System:

Lines Dry ☐ Enter ___ lb (Table 1-5)
Lines Wet ☐ Enter Zero

18 H_2O_2 System:

Lines Dry ☐ Enter ___ lb (Table 1-7)
Lines Wet ☐ Enter Zero

Remarks and Special Instructions:

NO.	ITEM AND SOURCE			WEIGHT W POUNDS	ARM X INCHES	MOMENT W_x POUND-INCHES	ARM Y INCHES	MOMENT W_y POUND-INCHES	ARM Z INCHES	MOMENT W_z POUND-INCHES
3	Basic Vehicle (Basic Wt and Balance Record,) (Form II-6)									
4	Pilot (Table 1-3)									
5	Corrections									
6	Vehicle (Less Gimballed Eqpt) at O.W.E. - Unbalanced									
7	Adjust Aft Equipment Vertically. (Paragraph 2.6.) Calculations:									
8	Vehicle (Less Gimballed Eqpt) at O.W.E.-Balanced Vertically									
9	Gimballed Eqpt (Basic Wt and Balance Record (Form II-4)									
10	Corrections:									
11	Basic Vehicle at O.W.E. - Unbalanced									
12	Adjust Aft Equipment, Lat and Horiz. (Paragraph 2.6.) Calculations:									
13	Vehicle at O.W.E. - Balanced									
14	Total JP4 Fuel Loaded		lb							
15	Less Fuel in Lines	-	lb	(Table 1-5)						
16	Total JP4 in Tanks		lb	(Table 1-4)	200.0		200.0			
17	Total H_2O_2 Loaded		lb							
18	Less H_2O_2 in Lines	-	lb	(Table 1-7)						
19	Total H_2O_2 in Tanks		lb	(Table 1-6)	200.0		200.0			
20	Gross Take Off Weight - Balanced									
21	Max. Allowable Gross Take Off Weight									
22	Difference: - Over ☐ Under ☐ Max. Allowable									

24 This Weight and Balance Clearance Applies Only to the Specific Flight and Date for Which it is Issued.

COMPUTED BY:	WT AND BALANCE AUTHORITY:	PILOT:
_____ Date _____	_____ Date _____	Date _____ Time _____

Lines between two spaces on the form indicate that a comparison is to be made. Arrows indicate that a value is to be transferred.

3.2.3. Use of Weight and Balance Clearance Form. - The following instructions are numbered to identify the various computations with the appropriate spaces on Form III-1.

Step 1. Insert the necessary identifying information at the top of the form.

Step 2. In the blank spaces of the LIMITATIONS table, enter the maximum allowable gross takeoff weight and minimum landing fuel restrictions obtained from the flight plan.

Step 3. Enter the vehicle basic weight, arms, and moments. Obtain these figures from the latest entry on the Basic Weight and Balance Record Form II-6.

Step 4. Add the pilot weight and moments using Table 1-3 and the pilot weight entered in Step 1.

Step 5. If the vehicle differs from the basic configuration used in Step 3, adjust here for any corrections which are required to bring the vehicle weight to actual flight status. Corrections should be limited to adjustments for last minute additions or removals of equipment. Changes incorporated at this point should be temporary. All permanent changes must be reflected in the basic weight and balance record form. Refer to Paragraph 2.5.7.

Step 6. Add together lines from Steps 3, 4, and 5 and obtain the weight and vertical center of gravity of the vehicle (less gimballed items) at operating weight empty.

Step 7. Compare the vertical center of gravity obtained in Step 6 with the limitations in Step 2. If the center of gravity falls within the limits, proceed to Step 8. If the center of gravity is outside the limits, the aft equipment platform must be adjusted either up or down to correct. First determine which unit of the movable equipment is to be adjusted and obtain its latest weight from the Basic Weight Record - Movable Equipment, Form II-7. Determine the moment required to correct the vehicle center of gravity and divide by the movable unit weight. This will give the required movement in inches.

Let W_1 = weight of vehicle.

W_2 = weight of movable unit.

Δ_Z = distance which vehicle center of gravity must move to fall within limits.

Δ_u = distance which movable equipment unit must be moved to provide Δ_Z.

Then

$$\Delta_u = \frac{W_1 \times \Delta_Z}{W_2}$$

Adjust the movable unit as closely as possible to the figure obtained and enter the actual moment change in the space provided.

NOTE

Any change in location of the movable equipment must be entered in the Basic Weight and Balance Record Form II-6. It is extremely important that this record is kept current.

Step 8. Enter the weight from the line of Step 6 and the sum of the moments from the lines of Steps 6 and 7. Compute the new centers of gravity. Compare the value obtained for the vertical center of gravity with the limitations in Step 2. The vertical center of gravity should now fall within the limits.

Step 9. Enter the gimballed equipment basic weight and lateral and horizontal arms and moments. Obtain these figures from the latest entry on the Gimballed Equipment Basic Weight and Balance Record Form II-4.

Step 10. If the gimballed equipment differs from the basic configuration used in Step 9, adjust here for any corrections which are required to bring the gimballed equipment weight to actual flight status. Corrections should be limited to adjustments for last minute additions or removals of equipment.

NOTE

Changes incorporated here should be temporary. All permanent changes must be reflected in the Gimballed Equipment Basic Weight and Balance Record (Paragraph 2.4.5).

Step 11. Add lines from Steps 8 through 10 and obtain the vehicle operating weight empty and lateral and horizontal centers of gravity.

Step 12. Compare the centers of gravity obtained in Step 11 with the limitations in Step 2. If they are both within the limits, proceed to Step 13.

If the centers of gravity fall outside the limits, movable units on the aft equipment platform must be adjusted. Follow the procedure laid down in Step 7 and enter the actual moment changes in the spaces provided.

NOTE

Any change in location of the movable equipment must be entered in the Basic Weight and Balance Record Form II-6. It is extremely important that this record is kept current.

Step 13. Enter the weight from the line of Step 11 and sum the moments from Steps 11 and 12. Compute the lateral and horizontal centers of gravity of the vehicle at operating weight empty.

Compare these centers of gravity with the limitations in Step 2. They should now fall within the limits.

Step 14. Enter the total weight of JP4 fuel loaded into the vehicle. Ensure that the fuel weight difference between the two tanks does not exceed one pound at takeoff.

Step 15. Complete this block and enter the appropriate figure in the space provided. (Since the JP4 fuel contained in the lines between the tank outlets and engine fuel pump is part of the vehicle basic weight (refer to Paragraph 1.1), it must be subtracted here if the system was dry before loading commenced.)

Step 16. Subtract line of Step 15 from line of Step 14 and obtain the weight of JP4 fuel actually in the tanks. Using Table 1-4, enter the moments in the spaces provided.

Step 17. Enter here the total weight of hydrogen peroxide fuel loaded into the vehicle.. Ensure that the fuel weight difference between the two tanks does not exceed one pound at takeoff.

Step 18. Complete this block and enter the appropriate figure in the space provided. (Since the hydrogen peroxide contained in the lines between the tank outlets and thruster solenoid valves is part of the vehicle basic weight (refer to Paragraph 1.1),it must be subtracted here if the system was dry before loading commenced.)

Step 19. Subtract line of Step 18 from line of Step 17 and obtain the weight of hydrogen peroxide actually in the tanks. Using Table 1-6, enter the moments in the spaces provided.

Step 20. Add lines of Steps 13, 16, and 19 and obtain the vehicle gross takeoff weight and centers of gravity. The vertical center of gravity is obtained from line of Step 8.

Compare these centers of gravity with the limitations in Step 2 and ensure that they are still within the limits.

Step 21. Enter the maximum allowable gross takeoff weight from Step 2.

Step 22. Find the difference between Steps 20 and 21. Check the appropriate box and enter the weight difference in the space provided. If the vehicle is overweight; then either:

(a) Offload JP4 fuel and/or hydrogen peroxide as necessary.

(b) Run the engine until it has consumed sufficient fuel to reduce the weight to the point where the vehicle will lift off.

Step 23. It is important for reasons of flight safety that a check is made on the fuels remaining at landing. From Step 16 (JP4) or Step 19 (H_2O_2) enter the total fuel contained in the tanks. Subtract the amount of fuel which will be consumed during the flight. This figure should be obtained from the flight plan.

Compare the estimated landing fuel thus obtained with the minimum landing fuel limitation from Step 2. Load extra fuel as necessary to ensure that minimum landing requirements are met.

This block can also be used to determine how much fuel should be loaded onto the vehicle for any particular flight. The method is as follows:

(a) Enter the minimum landing fuel requirement in Step 23.

(b) Add to this the estimated fuel usage figure.

(c) Enter this total in Step 16 (JP4) or Step 19 (H_2O_2).

(d) Add to this, the value of Step 15 (JP4) or Step 18 (H_2O_2).

(e) Enter this total at Step 14 (JP4) or Step 17 (H_2O_2). This figure will be the total amount of fuel which must be loaded to complete the mission and meet the minimum landing fuel limitations.

Step 24. When computations are completed, the form should be signed and dated in the spaces provided. Use the remarks and special instructions block to call attention to any unusual features of the loading or balance of the vehicle.